REVISIONS TO THE STATE IMPLEMENTATION PLAN
FOR THE CONTROL OF OZONE AIR POLLUTION

ATTAINMENT DEMONSTRATION FOR THE
HOUSTON/GALVESTON
OZONE NONATTAINMENT AREA

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION
P.O. BOX 13087
AUSTIN, TEXAS 78711-3087

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The modeling appendices (9c-A through 9c-G) referenced in this document can be obtained from Elizabeth Carmack by phone at (512) 239-1652, or by e-mail at ecarmack@tnrcc.state.tx.us. Electronic modeling data files can be obtained from Bright Dornblaser by phone at (512) 239-1978, or by e-mail at bdornbla@tnrcc.state.tx.us. Appendix 9c-H can be obtained from Heather Evans at (512) 239-1970, by e-mail at hevans@tnrcc.state.tx.us, or via the commission's web page at: www.tnrcc.state.tx.us/oprd/rules/propadop.htm.

VI: Ozone Control Strategy

A. INTRODUCTION

This Introduction is intended to provide the reader with a broad overview context of the State Implementation Plan (SIP) revisions that have been submitted to the U.S. Environmental Protection Agency (EPA) by the State of Texas. Some sections may be obsolete or superceded by new revisions, but have been retained for the sake of historical completeness. The reader is referred to the body of the SIP for details on the current SIP revision.

Requirements for SIP specified in 40 Code of Federal Regulations Part 51.12 provide that "...in any region where existing (measured or estimated) ambient levels of pollutant exceed the levels *specified* by an applicable national standard," the plan shall set forth a control strategy which shall provide for the degree of emission reduction necessary for attainment and maintenance of such national standard. Ambient levels of sulfur dioxide (SO_2) and oxides of nitrogen (NO_x), as measured from 1975 through 1977, did not exceed the national standards set for these pollutants anywhere in Texas. Therefore, no control strategies for these pollutants were included in revisions to the Texas SIP submitted on April 13, 1979. Control strategies were submitted and approved for inclusion in the SIP for areas in which measured concentrations of ozone, total suspended particulate (TSP), or carbon monoxide (CO) exceeded a National Ambient Air Quality Standard (NAAQS) during the period from 1975 to 1977. On October 5, 1978, the Administrator of the EPA promulgated a lead ambient air quality standard. The Federal Clean Air Act (FCAA) Amendments of 1977 required that each state submit an implementation plan for the control of any new criteria pollutant. A SIP revision for lead was submitted in March 1981.

The control strategies submitted in 1979 provided by December 31, 1982 the amount of emission reductions required by EPA policy to demonstrate attainment of the primary NAAQS, except for ozone in the Harris County nonattainment area. For that area, an extension to December 31, 1987 was requested, as provided for in the FCAA Amendments of 1977.

Supplemental material, including emission inventories for volatile organic compounds (VOC) and TSP submitted with the 1979 SIP revisions, is included in Appendices H and O of the 1979 SIP submittal.

Proposals to revise the Texas SIP to comply with the requirements of the FCAA Amendments of 1977 were submitted to EPA on April 13, November 2, and November 21, 1979. On December 18, 1979 (44 FR 75830-74832), EPA approved the proposed revision to the Texas SIP relating to vehicle inspection and maintenance and extended the deadline for attainment of the NAAQS for ozone in Harris County until December 31, 1987. (See Appendix Q of the 1979 SIP submittal for the full text of the extension request and the approval notice.) On March 25, 1980 (45 FR 19231-19245), EPA approved and incorporated into the Texas SIP many of the remaining provisions included in the proposals submitted by the state in April and November 1979. The March 25, 1980 *Federal Register* notice also included conditional approval of a number of the proposed SIP revisions submitted by the state.

Additional proposed SIP revisions were submitted to EPA by the state on July 25, 1980 and July 20, 1981 to comply with the requirements of the March 25, 1980 conditional approvals. By May 31, 1982, all of the proposed revisions to the Texas SIP submitted to EPA in April and November 1979, July 1980, and July 1981, with the exception of provisions relating to the definition of major modification used in new source review (NSR) and certain portions of the control strategy for TSP in Harris County, had been fully approved or addressed in a *Federal Register* notice proposing final approval. The NSR provisions were approved on August 13, 1984.

The FCAA Amendments of 1977 required SIPs to be revised by December 31, 1982 to provide additional emission reductions for those areas for which EPA approved extensions of the deadline for attainment of the NAAQS for ozone or CO. Paragraph B.5. of this section of the SIP contains the revision to the Texas SIP submitted to comply with the FCAA Amendments of 1977 and EPA rules for 1982 SIP revisions. Supplementary emissions inventory data and supporting documentation for the revision are included in Appendices Q through Z of the 1982 SIP submittal.

The only area in Texas receiving an extension of the attainment deadline to December 31, 1987 was Harris County for ozone. Proposals to revise the Texas SIP for Harris County were submitted to EPA on December 9, 1982. On February 3, 1983, EPA proposed to approve all portions of the plan except for the Vehicle Parameter Inspection/Maintenance (I/M) Program. On April 30, 1983, the EPA Administrator proposed sanctions for failure to submit or implement an approvable I/M program in Harris County. Senate Bill 1205 was passed on May 25, 1983 by the Texas Legislature to provide the Texas Department of Public Safety with the authority to implement enhanced vehicle inspection requirements and enforcement procedures. On August 3, 1984, EPA proposed approval of the Texas SIP pending receipt of revisions incorporating these enhanced inspection procedures and measures ensuring enforceability of the program. These additional proposed SIP revisions were adopted by the state on November 9, 1984. Final approval by EPA was published on June 26, 1985.

Although the control strategies approved by EPA in the 1979 SIP revisions were implemented in accordance with the provisions of the plan, several areas in Texas did not attain the primary NAAQS by

December 31, 1982. On February 23, 1983, EPA published a *Federal Register* notice identifying those areas and expressing the intent to impose economic and growth sanctions provided in the FCAA. However, EPA reversed that policy in the November 2, 1983 *Federal Register*, deciding instead to call for supplemental SIP revisions to include sufficient additional control requirements to demonstrate attainment by December 31, 1987.

On February 24, 1984, the EPA Region 6 Administrator notified the Governor of Texas that such supplemental SIP revisions would be required within one year for ozone in Dallas, Tarrant, and El Paso Counties and CO in El Paso County. The Texas Air Control Board (TACB) requested a 6-month extension of the deadline (to August 31, 1985) on October 19, 1984. EPA approved this request on November 16, 1984.

Proposals to revise the Texas SIP for Dallas, Tarrant, and El Paso Counties were submitted to EPA on September 30, 1985. However, the revisions for Dallas and Tarrant Counties did not provide sufficient reductions to demonstrate attainment of the ozone standard and on July 14, 1987, EPA published intent to invoke sanctions. Public officials in the two counties expressed a strong desire to provide additional control measures sufficient to satisfy requirements for an attainment demonstration.

A program of supplemental controls was taken to public hearings in late October 1987. As a result of testimony received at the hearings, a number of the controls were modified and several were deleted, but sufficient reductions were retained to demonstrate attainment by December 31, 1991. These controls were adopted by the TACB on December 18, 1987 and were submitted to EPA as proposed revisions to the SIP. Supplemental data and supporting documentation are included in Appendices AA through AO of the 1987 SIP submittal.

The FCAA Amendments of 1990 authorized EPA to designate areas failing to meet the NAAQS for ozone as nonattainment and to classify them according to severity. The four areas in Texas and their respective classifications include: Houston/Galveston (severe), Beaumont/Port Arthur (serious), El Paso (serious), and Dallas/Fort Worth (moderate).

The FCAA Amendments required a SIP revision to be submitted for all ozone nonattainment areas classified as moderate and above by November 15, 1993 which described in part how an area intends to decrease VOC emissions by 15%, net of growth, by November 15, 1996. The amendments also required all nonattainment areas classified as serious and above to submit a revision to the SIP by November 15, 1994 which described how each area would achieve further reductions of VOC and/or NO_x in the amount of 3.0% per year averaged over three years and which includes a demonstration of attainment based on modeling results using the Urban Airshed Model (UAM). In addition to the 15% reduction, states were also required to prepare contingency rules that will result in an additional 3.0% reduction of either NO_x or VOC, of which up to 2.7% may be reductions in NO_x. Underlying this substitution provision is the recognition that NO_x controls may effectively reduce ozone in many areas and that the design of strategies is more efficient when the characteristic properties responsible for ozone formation and control are evaluated for each area. The primary condition to use NO_x controls as contingency measures is a demonstration through UAM modeling that these controls will be beneficial toward the reduction of ozone. These VOC and/or NO_x contingency measures would be implemented immediately should any area fall short of the 15% goal.

Texas submitted rules to meet the Rate-of-Progress (ROP) reduction in two phases. Phase I consisted of a core set of rules comprising a significant portion of the required reductions. This phase was submitted by the original deadline of November 15, 1993. Phase II consisted of any remaining percentage toward the 15% net of growth reductions, as well as additional contingency measures to obtain an additional 3.0% of reductions. Phase II was submitted by May 15, 1994. The complete list of contingency measures was submitted by November 15, 1994. The appropriate compliance date was to be incorporated into each control measure to ensure that the required reductions will be achieved by the November 15, 1996 deadline. A commitment listing the potential rules from which the additional percentages and contingency measures were selected was submitted in conjunction with the Phase I SIP on November 15, 1993. That list of Phase II rules was intended to rank options available to the state and to identify potential rules available to meet 100% of the targeted reductions and contingencies. Only those portions of the Phase II rules needed to provide reasonable assurance of achieving the targeted reduction requirements were adopted by the commission.

The Dallas/Fort Worth and El Paso areas achieved sufficient reductions with the 15% ROP SIP to demonstrate attainment by 1996. Attainment Demonstration SIP Revisions for these two areas were submitted on September 14, 1994.

The FCAA Amendments of 1990 classified the Beaumont/Port Arthur area as a serious nonattainment area. The Beaumont/Port Arthur nonattainment area includes Hardin, Jefferson, and Orange Counties. The Beaumont/Port Arthur nonattainment area has an ozone design value of 0.16 ppm, which places the area in the serious classification.

The FCAA Amendments of 1990 require a Post-96 ROP SIP revision and accompanying rules to be submitted by November 15, 1994. According to the FCAA Amendments, this submittal had to contain an Attainment Demonstration based on UAM. Additionally, the revision had to demonstrate how the Houston/Galveston and Beaumont/Port Arthur nonattainment areas intend to achieve a 3% per year reduction of VOC and/or NO_x until the year 2007, and additional reductions as needed to demonstrate modeled attainment. The plan was also required to carry an additional 3% of contingency measures to be implemented if the nonattainment area fails to meet a deadline. To use NO_x reductions for all or part of the Post-96 controls or the contingency measures required a demonstration using UAM showing that NO_x controls would be beneficial in reducing ozone.

On November 9, 1994, the state submitted a SIP revision designed to meet the 3% per year ROP requirements for the years 1997-1999. This Post-96 ROP SIP revision detailed how the Beaumont/Port Arthur and Houston/Galveston nonattainment areas intend to achieve these three years' reductions of VOC (or 9% net-of-growth). Most of this amount was achieved by quantifying additional reductions due to existing rules and reductions due to federally-mandated rules. Rules to achieve the further reductions needed to meet the ROP SIP goal were submitted to EPA on January 11, 1995. This submittal included modeling demonstrating progress toward attainment, using a 1999 future year emissions inventory.

On August 14, 1994, the state submitted preliminary UAM modeling results for the Beaumont/Port Arthur and Houston/Galveston nonattainment areas that showed the relationship between emission levels of VOC and NO_x, and ozone concentrations. This modeling was conducted with a 1999 future year emissions inventory. Based on the results of this preliminary modeling, which showed that NO_x reductions might increase ozone concentrations, on April 12, 1995 the state received a temporary Section 182(f) exemption from all NO_x requirements including reasonably available control technology (RACT), I/M, NO_x NSR, and transportation conformity requirements. Permanent §182(f) exemptions from all NO_x requirements were granted for Dallas/Fort Worth and El Paso, and temporary exemptions until December 31, 1996 for Houston/Galveston and Beaumont/Port Arthur. The commission subsequently requested that EPA extend this date until December 31, 1997. EPA approved this 1-year extension on May 14, 1997.

On March 2, 1995, Mary Nichols, EPA Assistant Administrator for Air and Radiation, issued a memo which gave states some flexibility to design a phased Attainment Demonstration. It provided for an initial phase which was intended to continue progress in reducing levels of VOC and/or NO_x while giving states an opportunity to address scientific issues such as modeling and the transport of ozone and its precursor pollutants. The second phase was designed to draw upon the results of the scientific effort and design a plan to bring the area into attainment. To constitute Phase I under this approach, the EPA guidance required that states submit the following SIP elements by December 31, 1995:

- Control strategies to achieve reductions of ozone precursors in the amount of 3% per year from the 1990 baseline emissions inventory (EI) for the years 1997, 1998, and 1999.
- UAM modeling out through the year 1999, showing the effect of previously-adopted control strategies which were designed to achieve a 15% reduction in VOCs from 1990 through 1996.
- A demonstration that the state has met the VOC RACT requirements of the FCAA Amendments.
- A detailed schedule and plan for the "Phase II" portion of the attainment demonstration which will show how the nonattainment areas can attain the ozone standard by the required dates.
- An enforceable commitment to:
    - Participate in a consultative process to address regional transport,
    - Adopt additional control measures as necessary to attain the ozone NAAQS, meet ROP requirements, and eliminate significant contribution to nonattainment downwind, and
    - Identify any reductions that are needed from upwind areas to meet the NAAQS.

Texas submitted the first two of these required sections in November 1994. The remaining three, a VOC RACT demonstration, the required commitments, and a Phase II plan and schedule, were submitted on January 10, 1996 to EPA.

ROP SIP modeling was developed for the Houston/Galveston nonattainment area in two phases using the UAM. The first phase of ROP modeling was the modeling submitted in January 1995, as described above. The second phase of the ROP modeling was conducted using data obtained primarily from the Coastal Oxidant Assessment for Southeast Texas (COAST) project, an intensive 1993 field study. The COAST modeling for Houston/Galveston and the associated SIP were projected to be completed by December 1996 for submittal in May of 1997. Control strategies developed in this second phase were planned to be based on a more robust data base, providing a higher degree of confidence that the strategies would result in attainment of the ozone NAAQS or target ozone value. A discussion of the schedule for the UAM modeling for the Phase II Attainment Demonstration can be found in Appendix 11-F of the January 10, 1996 submittal.

On January 29, 1996, the EPA proposed a limited approval/limited disapproval for the Texas 15% ROP SIP revision. The EPA proposed a limited approval because the SIP revision will result in significant emission reductions from the 1990 baseline, and will, therefore, improve air quality. Simultaneously, the EPA proposed a limited disapproval because they believe that the plan fails to demonstrate sufficient reductions to meet the 15% ROP requirements. They also proposed a limited approval/disapproval of the contingency plans (designed to achieve an additional 3% of reductions if needed because a milestone is missed) along the same lines as the 15% action. The EPA stated that some of the control measures submitted along with the SIP revision did not meet all of the requirements of the FCAA Amendments of 1990, and, therefore, cannot be approved. The EPA further stated that they were not making a determination at this time whether the state has met its requirements regarding RACT, or any other underlying FCAA Amendments of 1990 requirements. Finally, the EPA proposed approval of the Alternate Means of Control portion of the November 9, 1994 Post-96 SIP submittal, but did not propose action on any other portion of that submittal.

Additionally, on November 29, 1995, the President signed the National Highway Systems Designation Act, which, among other things, prohibited EPA from discounting the creditable emissions from a decentralized vehicle I/M testing program if an approvable conditional I/M SIP revision was submitted to EPA within 120 days of the bill's signature. EPA's Office of Mobile Sources issued guidance stating that they would accept an interim I/M SIP proposal and Governor's letter 120 days after signature of the bill in lieu of an adopted SIP revision. The SIP proposal and letter was submitted to the EPA prior to the March 27, 1996 deadline to meet the 120 day time frame. The final I/M SIP revision (Rule Log No. 96104-114-AI), commonly referred to as the "Texas Motorist's Choice Program," was adopted by the commission on May 29, 1996 and submitted to the EPA by the state on June 25, 1996. On October 3, 1996, EPA proposed (61 FR 51651-51659) conditional interim approval of the Texas Motorist's Choice Program based upon the state's good faith estimate of emission reductions and the program's compliance with the Clean Air Act.

Part of EPA's determination that the new I/M SIP is approvable depends on the program's ability to achieve sufficient creditable VOC reductions so that the 15% ROP can still be achieved. The commission designed the revised I/M program to fit in with the other elements of the 15% SIP to achieve the full amount of creditable reductions required. The I/M program also achieves creditable reductions for the Post-96 ROP SIP.

Changes to the I/M program have had an impact on the El Paso §818 Attainment Demonstration as well. This demonstration was predicated on the assumption that the I/M program would be implemented as adopted for the 15% SIP. An addendum to the §818 Demonstration shows that the basic underlying assumptions of the modeling still pertain despite the revisions to the I/M program.

The Employer Trip Reduction (ETR) program revision to the SIP and ETR rule were adopted in October 1992 by the TACB to meet the mandate established in the FCAA Amendments of 1990 (§182 (d) (1) (B)). This section of the FCAA required states with severe or extreme ozone nonattainment areas to develop and implement ETR programs in those areas. For Texas, the only area affected was the Houston/Galveston area. The ETR program required large employers (those with 100 or more employees) to implement trip reduction programs that would increase the average passenger occupancy rate of vehicles arriving at the workplace during the peak travel period by 25% above the average for the area.

Congress amended the FCAA in December of 1995 by passing House Rule 325. This amendment allows the state to require an ETR program at its discretion. It also allows a state to "remove such provisions (ETR program) from the implementation plan…if the state notifies the Administrator, in writing, that the state has undertaken, or will undertake, one or more alternative methods that will achieve emission reductions (1.81 tons/day) equivalent to those achieved by the removed…provisions." As such, large employers will no longer be mandated to implement trip reduction programs. The Houston/Galveston ozone nonattainment area will, however, through the coordination of the Houston-Galveston Area Council, implement a voluntary regional initiative to reduce vehicle trips.

The 1990 Adjusted Base Year EI was submitted on November 12, 1993. It is the official inventory of all emission sources (point, area, on-road and off-road mobile) in the four nonattainment areas. There have been several changes to the EI due to changes in assumptions for certain area and non-road mobile source categories. Changes to the baseline EI have affected the target calculations and creditable assumptions made in the 15% and 9% SIPs.

In December of 1990, then-Texas Governor William Clements requested that the Beaumont/Port Arthur area be reclassified as a "moderate" ozone nonattainment area in accordance with Section 181(a)(4) of the FCAA Amendments of 1990. That request was denied on February 13, 1991. A recent review of the original request and supporting documentation has revealed that this denial was made in error. As provided by Section 110(k)(6) of the Act, the EPA Administrator has the authority to reverse a decision regarding original designation if it is discovered that an error had been made.

Monitoring data from a privately-funded, special purpose monitoring network which was not included in the Aerometric Information Retrieval System database was improperly used to deny this request. Furthermore, subsequent air quality trends demonstrated that Beaumont/Port Arthur is more properly classified as a moderate nonattainment area, and could attain the standard by the required date for moderate areas of November 15, 1996. Therefore, Governor Bush sent a letter and technical support to EPA on July 20, 1995, requesting that the Beaumont/Port Arthur area be reclassified to moderate nonattainment status. Beaumont/Port Arthur planned to demonstrate attainment one of the following ways:

- Monitored values showing attainment of the standard at state-operated monitors for the years 1994-1996, which is the time line the FCAA Amendments of 1990 specifies for moderate areas.

- ♦ UAM modeling showing attainment of the standard but for transport of ozone and/or precursors.

EPA Region VI verified the data submitted in support of this request, and concurred that it is valid. On June 3, 1996, the reclassification of the Beaumont/Port Arthur area became effective. Because the area was classified as serious, it was following the SIP submittal and permitting requirements of a serious area, which included the requirements for a Post-96 SIP. With the consolidated SIP submittal, the commission removed the Beaumont/Port Arthur area from the Post-96 SIPs, which became applicable to the Houston/Galveston nonattainment area only.

The State of Texas, in a committal SIP revision submitted to EPA on November 15, 1992, opted out of the Federal Clean Fuel Fleet program in order to implement a fleet emission control program designed by the state. In 1994, Texas submitted the state's opt-out program in a SIP revision to the EPA and adopted rules to implement the Texas Alternative Fuel Fleet (TAFF) program. In 1995, the 74th Texas Legislature modified the state's alternative fuels program through passage of Senate Bill (SB) 200. In response to SB 200, the commission adopted regulations modifying the TAFF program to create the Texas Clean Fleet (TCF) program.

Since adoption, on July 24, 1996, and subsequent submission to EPA of the TCF SIP revision, the 75th Texas Legislature modified the state's alternative program once again through passage of SB 681. Staff is currently working on modifications to the TCF program, now called the TCF Low Emission Vehicle program, to reflect changes mandated by SB 681.

On June 29, 1994 the commission adopted a revision to the SO_2 SIP regarding emissions in Harris County. The SIP revision was required by EPA because of exceedances of the SO_2 NAAQS in 1986, 1988, and 1990. An EPA study conducted by Scientific Applications International Corporation also predicted SO_2 exceedances. On April 22, 1991 the EPA declared that portions of Harris County were potentially in nonattainment of the SO_2 NAAQS. Consequently, the Houston Regional Monitoring (HRM) Corporation volunteered to find reductions in SO_2 in order to prevent being redesignated to nonattainment. HRM's efforts resulted in finding voluntary SO_2 reductions. These reductions were adopted in thirteen commission Agreed Orders and were included as part of the June 29, 1994 SIP revision. The EPA approved the Harris County SO_2 SIP on March 6, 1995 (60 FR 12125).

On May 14, 1997, the commission adopted an additional revision to the Harris County SO_2 SIP to incorporate modifications to two of the thirteen commission Agreed Orders. The remaining sections of the SIP remained the same. While on the scale of "minor technical corrections," the modified orders were submitted as a SIP revision because the new emission rates differ from what EPA had previously approved. The two agreed order modifications concerned grandfathered units at Simpson Pasadena Paper Company and Lyondell-Citgo Refining Company, Ltd. The commission approved changes to both Agreed Orders on July 24, 1996.

On May 14 ,1997, the commission also adopted a revision to the SIP modifying the vehicle I/M program. This revision removed the test-on-resale component that had been included in the vehicle I/M program, as designed in July of 1996. Test-on-resale required persons selling their vehicles in the I/M core program areas to obtain emissions testing prior to the title transfer of such vehicles. Test-on-resale was not required to meet the FCAA Amendments of 1990 and did not produce additional emissions reduction benefits. The SIP revision also incorporated into the SIP the Memorandum of Understanding between the commissions and the Department of Public Safety, adopted by the commission on November 20, 1996.

The FCAA Amendments of 1990 required that, for severe and above ozone nonattainment areas, states develop SIP revisions that include specific enforceable transportation control measures (TCMs), as necessary, to offset increases in motor vehicle emissions resulting from growth in vehicle miles traveled (VMT) or the number of vehicle trips. This SIP revision would also satisfy reductions in motor vehicle emissions consistent with the 15% ROP and the Post-1996 ROP SIPs.

Therefore, the commission developed and submitted to EPA a committal SIP revision for the Houston/Galveston nonattainment area on November 13, 1992, and VMT Offset SIP revisions on November 12, 1993, and November 6, 1994, to satisfy the requirements of the 15% ROP SIP revision. The former SIP revision laid out a set of TCMs and other mobile source controls which reduced emissions below the modeled ceiling. The 1994 SIP revision did not require additional TCMs.

As a result of changes in the I/M and the ETR programs, it was necessary to do the 1997 VMT Offset SIP revision for the Houston/Galveston area, which was adopted on August 6, 1997. Additional TCMs were included: High Occupancy Vehicle Lanes, Park and Ride Lots, Arterial Traffic Management Systems, Computer Transportation Management Systems, and Signalization. These TCMs were part of the "Super SIP" submitted to EPA on July 24, 1996.

Using the best technical guidance and engineering judgement available at the time, the state of Texas calculated emissions reductions available from the enhanced monitoring rule that was to be part of the Title V permitting program. The enhanced monitoring rule was later revised and transformed into the Compliance Assurance Monitoring (CAM) Rule. Texas maintained that their calculation methodologies still accurately reflected the amount of creditable reductions available. EPA has indicated that they disagree with the calculation methodologies used by the state and intend to disapprove the 9% SIP as a result. EPA has also indicated that the emission reduction credits claimed for the Texas Clean Fuels Fleet program are not approvable due to a legislative change to the program. The state plans to submit a SIP revision for this program in a separate action, but has removed the credits claimed in the 9% SIP in this action. The state of Texas proposes to submit a revision to the 9% SIP which revises the reductions claimed by the state toward the 9% emissions target.

The State of Texas did not re-apply for an extension of the NO_x 182(f) waivers for Houston/Galveston and Beaumont/Port Arthur as discussed previously. Therefore, on December 31, 1997, it expired. The state will now be required to implement several NO_x control programs. Among them is a requirement for all major NO_x sources within the area to implement RACT. The state has proposed a revised compliance date for this program of November 30, 1999. The state believes that this program, taken in concert with the approvable VOC measures in the existing Post-96 SIP, will satisfy the ROP requirements of that SIP.

On July 18, 1997, EPA promulgated a new 8-hour NAAQS for ozone. This standard is intended to replace the previous 1-hour standard. However, EPA decided that areas would not be subject to the new 8-hour standard until they had attained the 1-hour standard. Therefore, on December 29, 1997, EPA issued guidance on requirements for areas that have not yet attained the 1-hour standard. In Texas, this includes Dallas/Fort Worth, Beaumont/Port Arthur, El Paso, and Houston/Galveston. Each area has a unique set of circumstances which will be addressed in future SIP submittals. In this action, the state is proposing a SIP revision to address attainment demonstration requirements as discussed in the December 29, 1997 EPA guidance.

A complete discussion of the December 29, 1997 guidance requirements and how the state intends to meet those requirements can be found in Section B.9.c.1). In summary, among other elements, the guidance requires a SIP revision to be submitted to EPA by April 1998. The state of Texas intends to meet this requirement by submitting a SIP revision which contains UAM modeling based on the COAST study described above, identification of the level of controls necessary to achieve attainment of the 1-hour ozone standard, identification of emissions sources for potential future control strategies, and a commitment schedule for future attainment demonstration SIP submittals.

B. OZONE CONTROL STRATEGY

1. POLICY AND PURPOSE (Revised.)

a. Primary Purpose of the Plan (Revised.)

The primary purpose of this plan is to fulfill §182(c)(2) of the FCAA Amendments of 1990 concerning Attainment and Reasonable Further Progress Demonstrations, and various EPA guidance.

b.-d. (No change.)

2. SUMMARY OF THE PRINCIPAL ELEMENTS ADDRESSED WITHIN THIS PLAN (Revised.)

a.-c. (No change.)

d. Required Emission Reductions (Revised.)

This plan contains a revision to the emission reductions needed to achieve the 9% ROP SIP target. Details regarding this plan can be found in §VI.B.11.c.

This plan contains an estimate of the required levels of reductions of the ozone precursors VOC and NO_x necessary to achieve attainment of the 1-hour ozone standard in the Houston/Galveston nonattainment area by the year 2007. These estimates are based on EPA protocols for projecting the EI from the 1993 urban airshed modeling base case EI out to 2007. The urban airshed model was the tool used to determine the required level of reductions. Details regarding this plan can be found in §VI.B 9.c.

e. Sources of Emission Reductions (Revised.)

Substantial quantities of VOC and NO_x are emitted by business, industry, consumer products, and motor vehicles. For the 9% SIP revision, this plan identifies the control strategies which will be used to make up the shortfall in the 9% plan due to the loss of the creditable reductions claimed for the CAM rule and for the Texas Clean Fuels Fleet program.

For the Houston/Galveston Attainment Demonstration, this plan identifies the various source categories that the state will investigate for possible future control strategies. The state began by evaluating likely new federal measures that would apply to the Houston/Galveston area before 2007. The state also looked to continuing emission reductions from existing rules in place in the area. Finally, the state worked with various stakeholders in the local area to evaluate other source categories and control strategies for potential future emission reductions.

3. OZONE CONTROL PLAN FOR 1979 SIP REVISION (No change.)

4. CONTROL STRATEGY FOR 1979 SIP REVISION (No change.)

5. 1982 HARRIS COUNTY SIP REVISION (No change.)

6. SIP REVISIONS FOR POST-1982 URBAN NONATTAINMENT AREAS (No change.)

7. SIP REVISIONS FOR 1993 RATE-OF-PROGRESS (No change.)

8. SIP REVISIONS FOR MOBILE SOURCES (No change.)

   a. Vehicle Inspection/Maintenance (I/M) Program (No change.)
   b. Vehicle Miles Traveled Offset (No change.)
   c. Employer Trip Reduction Program. (Repealed.)

9. SIP REVISIONS FOR THE ATTAINMENT DEMONSTRATION (Revised.)

   a. El Paso §818 Attainment Demonstration (No change.)
   b. Dallas/Fort Worth Attainment Demonstration (No change.)
   c. Houston/Galveston Attainment Demonstration (Revised.)

1) Background

The Houston/Galveston ozone nonattainment area is classified as Serious-17, and therefore it is required to attain the 1-hour ozone standard of 0.12 parts per million by November 15, 2007. The Houston/Galveston area has been working to develop a demonstration of attainment in accordance with the FCAA Amendments of 1990. On January 4, 1995, Houston submitted the first of its Post-1996 SIP revisions.

This SIP consisted of Urban Airshed Modeling for 1988 and 1990 base case episodes, adopted rules to achieve a 9% ROP reduction in VOCs, and a commitment schedule for the remaining ROP and attainment demonstration elements. At the same time, but in a separate action, the State of Texas filed for the temporary NO_x waiver allowed by Section 182(f) of the FCAA Amendments of 1990. This SIP and the NO_x waiver were based on early base case episodes, which, while they performed in accordance with EPA modeling performance standards, had a limited data set as inputs to the model. In 1993 and 1994, the commission was engaged in an intensive data-gathering exercise known as the Coastal Oxidant Assessment for Southeast Texas, or COAST, study. The state believed that the enhanced EI, expanded ambient emissions and meteorological monitoring, and other elements would provide a more robust data set for modeling and other analysis, which would lead to modeling results that the commission could use to better understand the nature of the ozone air quality problem in the Houston/Galveston area. This modeling has been ongoing since that time.

Concurrent with this has been the changing national policy regarding SIP elements and time lines from EPA at a national level. Two national programs in particular have resulted in changing deadlines and requirements. The first of these programs has been the Ozone Transport Assessment Group (OTAG).

This group grew out of a March 2, 1995 memo from Mary Nichols that allowed states to postpone completing their attainment demonstrations until after an assessment of the role of transported ozone and precursors had been completed for the eastern two-thirds of the nation, including the eastern portion of Texas. Texas participated in this study, and it has been concluded that Texas does not significantly contribute to ozone exceedances in the Northeastern U.S. The other major national program has been the revision to the national ozone standard. EPA promulgated a final rule on July 18, 1997 changing the ozone standard to an 8-hour standard of .08 ppm. In November 1996 concurrent with the proposal of the standard's, EPA had proposed an interim implementation policy (IIP) that they believed would help areas like the Houston/Galveston area transition from the old to the new standard. In an attempt to avoid a significant delay in planning activities, Texas began to follow this guidance, and readjusted its modeling and SIP development time lines accordingly. When the new standard was published, EPA decided not to publish the IIP, and instead told areas that currently exceed the 1-hour ozone standard that it will continue to apply until it is attained, which the 1990 FCAA Amendments requires by November 15, 2007 for Houston/Galveston.

EPA has recently published revised guidance for areas like Houston/Galveston that do not attain the 1-hour ozone standard. The State of Texas proposes the following elements to respond to this guidance (the state elements are in boldface):

- Evidence that all measures and regulations required for the nonattainment area by subpart 2 of Title I of the FCAA to control ozone and its precursors have been adopted and implemented or are on an expeditious schedule to be adopted and implemented.

Texas has submitted all previous SIP revisions required for the Houston/Galveston area.

- A list of measures and regulations and/or a strategy including technology forcing controls needed to meet ROP requirements and attain the 1-hour NAAQS.

This SIP contains a strategy that the state could follow to meet ROP requirements and attain the standard in Houston/Galveston. This strategy is comprised of a list of control measures and regulations and potential technology forcing controls. The strategy has four parts--a quantification of expected federal measures that will achieve reductions in VOC and NO_x by 2007, a list of planned state measures, a list of control measures that the local Houston/Galveston area can debate and recommend to the state for adoption, and a set of measures for further study for their usefulness in reducing ozone in Texas. The strategy also outlines a process that the state will follow over the next several years to select the most beneficial and cost-effective reductions for the area.

- For severe and higher classified areas, a SIP commitment to submit a plan on or before the end of 2000 which contains, a) target calculations for Post-1999 ROP milestones up to the attainment date, (unless already submitted to satisfy EPA's previous findings of failure to submit), and b) adopted regulations needed to achieve the Post-1999 ROP requirements up to the attainment date and to attain the 1-hour NAAQS (note that for many states EPA has proposed in its regional NO_x SIP call to require a submittal of NO_x reduction programs by the earlier date of September 1999, and that reductions from these programs can contribute to achieving ROP.)

This SIP revision contains a commitment to submit a plan on or before the end of 2000 which contains target calculations for Post-1999 ROP milestones up to the attainment date and adopted

regulations needed to achieve the Post-1999 ROP requirements up to the attainment date and to attain the 1-hour NAAQS.

- A SIP commitment and schedule to implement the control programs and regulations in a timely manner to meet ROP and achieve attainment.

This SIP revision contains a commitment and schedule to implement the control programs and regulations in a timely manner to meet ROP and achieve attainment.

- Evidence of a public hearing on the state submittal.

This SIP revision will be taken through the standard public hearing process. Information on the public hearing can be found in Section B.14.

The following elements are included in this SIP.

- Urban Airshed Modeling projecting emissions from a 1993 baseline out to the 2007 attainment date.
- An estimate of the level of control of VOC and NO_x necessary to achieve the 1-hour ozone standard by 2007.
- Estimation of the levels of VOC and NO_x required to meet ROP targets.
- A list of control strategies that the state could implement to attain the 1-hour ozone standard
- A schedule for completing the other required elements of the attainment demonstration

- A revision to the Post-1996 9% ROP SIP that remedies a deficiency that EPA believes makes the previous version of that SIP unapprovable.

2) Basis for Attainment

The State of Texas has performed UAM modeling in accordance with EPA protocols and guidance. This modeling is based upon a multi-day episode that occurred in September 1993, during the intensive field study known as the COAST study. It is based on emissions which have been projected according to EPA guidance out to 2007, the Houston/Galveston attainment year.

This modeling indicates that reductions in NO_x in the amount of approximately 65-85% of the 1990 baseline EI will be required to attain the 1-hour standard. This range of NO_x reductions was determined using a weight of the evidence approach to analyzing the modeling results. EPA describes the weight of the evidence approach in their June 1996 Alternate Attainment Demonstration guidance. A detailed discussion of the modeling assumptions, protocols, and results is contained in §7.B.3) of this document.

The modeling further indicates that although VOC reductions will reduce ozone, a reduction of 100% of the anthropogenic VOCs would not be enough to bring the area into attainment. This is likely due to the influence of biogenic emissions within the domain as well as transported ozone and ozone precursors from outside the domain.

However, a moderate amount of VOC reductions of about 15% of the 1990 baseline will likely continue to play a role in the ozone strategy for Houston/Galveston. Although large amounts of NO_x reductions appear to be necessary for attainment, initial NO_x reductions in smaller amounts may cause a NO_x disbenefit. According to the model, initial NO_x reductions up to about 50% may increase peak ozone concentrations due to the complex photochemical reactions inherent in ozone formation. The modeling further shows that moderate amounts of VOC reductions should mitigate that effect. Analysis shows that a 15% reduction in VOC, beyond the 1999 ROP reductions, can be combined with NO_x reductions to ensure that no significant NO_x disbenefit occurs. Therefore, there does not seem to be a comparative advantage to making larger levels of VOC reductions past that point. There are several federal controls of point, area, on- and non-road mobile sources that are planned by EPA for phase-in over the next 10 years. The state of Texas will quantify these reductions first before adopting additional new VOC rules to achieve the 15% reduction.

3) Urban Airshed Modeling Results and Reports

a) Introduction

This section of the SIP document summarizes procedures and results of photochemical modeling conducted in support of the attainment demonstration for the Houston/Galveston ozone nonattainment area. The purpose of the modeling was to determine the level of reductions of ozone precursors necessary for demonstrating attainment of the 1-hour ozone NAAQS in the nonattainment area by the attainment year of 2007. Previous modeling, submitted with the ROP SIP in 1994, was conducted to demonstrate progress toward attainment of the standard based on a future year of 1999.

Topics which will be discussed in the following sections include:

- Overview of photochemical modeling process
- Quality Assurance/quality control
- Policy and technical oversight committees
- Overview of 1993 COAST Study
- Model selection
- Modeling domain
- Meteorological and air quality considerations, including ozone episode selection
- Base Case EI development and data
- Base Case modeling and model performance evaluation
- Future year inventory development
- Future year modeling - procedures, results, and conclusions

b) Overview of Photochemical Modeling Process

This section is intended to provide a very general overview of the processes involved in photochemical modeling for attainment demonstrations.

(1) Ozone Photochemistry

Ozone is not emitted directly into the atmosphere. This compound is formed by a complex photochemical process largely involving the chemical interaction of NO_x, VOC, and energy from sunlight. NO_x is a shorthand term describing all of the nitrogen oxides that participate in the ozone reaction. NO_x emissions emanate primarily from combustion sources such as industrial facilities, power plants, automobiles, and other engines. VOC is a shorthand term describing all of the volatile organic compounds that participate in the ozone chemistry. VOC emissions emanate from combustion sources, leaks at industrial facilities (fugitive emissions), and evaporation of fuel and solvents. A large amount of VOC emissions come from vegetation, particularly oak trees (biogenic emissions). Although we can reduce anthropogenic emissions of VOC, control of the biogenic portion of the emissions is not considered feasible.

Ozone concentrations tend to rise during the summer months because, in addition to being dependent upon emissions of NO_x and VOC, ozone formation is enhanced when there are light winds, high temperatures and ample sunlight.

(2) Model Input

Before a model can be used to simulate ozone formation in a region, a large amount of input data must be prepared and quality assured. The three main categories of input to a photochemical model are: emissions, meteorology, and air quality data. Since emissions are measured directly from only a small number of sources, most emissions data input into photochemical models are themselves the result of emissions models, some of which can be quite sophisticated. Similarly, the three-dimensional meteorology required by the photochemical model to simulate the movement and mixing of ozone and its precursors cannot be adequately described by a limited number of meteorological monitors. Sophisticated meteorological models are thus employed to furnish the photochemical model with the required atmospheric dynamics. Finally, air quality information is required to furnish the photochemical model with the levels of pollutants arriving in the region of interest (this is known as "transport"). Because air quality monitors, particularly in rural areas, are quite sparse, frequently a regional photochemical model is employed to provide an urban-scale photochemical modeling application with information on transported pollutants. In fact, most of the data input into a photochemical model is itself the result of preliminary modeling. The input and output of all these preliminary models must be carefully quality assured before being input into the photochemical model.

(3) Photochemical Model

Several photochemical models are specifically designed to simulate ozone formation in urban areas. The UAM is the model used by the commission staff for attainment demonstration modeling.

The UAM is extremely complex. It simulates the photochemical reactions involving NO_x and VOC as well as the meteorological processes which contribute to ozone formation (e.g., wind flow, atmospheric mixing, sunlight). This model characterizes the atmosphere over an area of interest with a three-dimensional grid that may include thousands of individual grid cells in the horizontal and vertical (see Figure 1). A powerful computer is required to keep track of the meteorological conditions in each cell, to add in emissions from every emission source in the grid, to calculate the amount of solar energy available, and to solve the chemical and physical equations that describe the formation of ozone in each grid cell.

Figure 1 UAM Grid Concept

(4) Modeling Process

The general UAM modeling process is shown in Figure 2. The procedure for UAM modeling starts with developing a modeling protocol, defining a modeling domain, and selecting one or more representative historical ozone episodes. Then, data required for running the model for the historical episodes (emissions, meteorological, and air quality data) are developed and input to the model, and the model is executed. This is usually called “base case” modeling. Once the model is run for the base case, a performance evaluation is conducted to determine how well the model predicted the ozone levels which actually occurred during the historical episodes. Performance is evaluated using EPA-approved evaluation criteria and performance limits. If the UAM performance is acceptable, then additional major modeling steps are performed. If performance is not acceptable, the model inputs are examined and may be modified, provided technically defensible.

Once the UAM base case performance is acceptable, emissions are projected to the nonattainment area’s attainment year. These future emissions are based on econometric forecasts which estimate the growth of industry, traffic and population in the future. Any existing state or federal regulations which will take effect between the base year and the attainment year are used to adjust the future inventory. At this point, the future inventory is a “base future inventory”. The model is then run using the base future EI, along with the meteorology from the base case episodes, to determine if the existing state and federal regulations reduce ozone sufficiently for the area to meet the NAAQS by the attainment year. If the existing regulations are not sufficient, then ozone precursor reduction targets are determined from the modeling results. That is, the modeling results at this point will indicate what *further* reductions of VOC and/or NO_x are needed for the area to attain the ozone standard.

Figure 2 UAM Model Application Process

Once additional candidate controls are developed, the model can be executed again to test the effectiveness of the controls in bringing the area of interest into attainment.

c) Quality Assurance/Quality Control

Extensive quality assurance/quality control (QA/QC) procedures were implemented as an essential element of the attainment demonstration modeling process for Houston/Galveston. QA/QC procedures were implemented for major attainment demonstration tasks including meteorological field development, EI preparation, model execution, and results interpretation. QA/QC procedures included internal peer review, reasonableness checks of input data and results, and application of statistical and graphical techniques, many of which were developed by commission staff, to input data and results. In addition to internal QA/QC, the commission contracted with EarthTech, Inc. to perform external peer review of the model input data preparation techniques. EarthTech's report, entitled *Peer Review of Urban Airshed Modeling* (Final Report) (1996), is available from the commission upon request.

Specific QA/QC procedures are discussed in the detailed reports contained in the modeling appendices.

d) Modeling Oversight Groups

Oversight for Houston/Galveston attainment demonstration modeling was provided by two groups consisting of members from a wide variety of organizations involved with or affected by SIP development. The Regional Air Quality Planning Committee provided oversight and review of photochemical modeling as related to policy implications. This group was coordinated by the Houston/Galveston Area Council, which is the Metropolitan Planning Organization for the

Houston/Galveston area. Table 1 lists the organizations participating in the work group along with the names of the individuals representing each organization.

Table 1. Urban Airshed Modeling Policy Oversight Committee

Name	Company/Organization
Karen Atkinson	Texas Natural Resource Conservation Commission - Houston Region
R. S. Barrett	Harris County Pollution Control
Delmar Barry	Waller County Commissioner
Raymond Campion	Mickey Leland National Urban Air Toxics Research Center
B. C. Carmine	Houston Lighting and Power Company
Jack Coblenz	Source
Guy Donaldson	EPA Region 6
Larry Feldcamp	Baker and Botts
Richard Flannery	Texas Natural Resource Conservation Commission - Houston Region
Mark Hainley	Chambers County
Winifred Hamilton	Galveston/Houston Association for Smog Prevention
David Hitchcock	Houston Advanced Research Institute
John Holden	Greater Houston Partnership
Dewayne Huckabay	City of Houston
Carole Lenz	Harris County Pollution Control
Jacqueline Lentz	Houston/Galveston Area Council
Gene McMullen	City of Houston
Henry Meredith	American Lung Association
Sandra Pickett	City of Liberty Councilwoman
Ronald Schultz	Galveston County
John Sedlak	Metropolitan Transit Authority
Robert Shaddox	Houston Area Bicycle Alliance
Steve Simmons	Texas Department of Transportation
Frances Smith	League of Women Voters
George Smith	Sierra Club
G. Michael White	City of Baytown
Mary Ellen Whitworth	City of Houston
Frank Yonish	Missouri City

The UAM Technical Oversight Committee had oversight of the technical aspects of the modeling. The members and affiliations of this work group are listed in Table 2.

Table 2. Urban Airshed Modeling Technical Oversight Committee

Name	Company/Organization
Ramon Alvarez	Environmental Defense Fund
Lilibeth Andre	City of Houston - Office of Engineering Management
Dan Baker	Shell Oil
Walter Crow	Radian International
James Davenport	Dow Chemical
Cyril Durrenberger	Texas Natural Resource Conservation Commission
D. Alan Hansen	Electric Power Research Institute
Dave Harper	Texas Natural Resource Conservation Commission
Albert Hendler	Radian International
John Holden	Shell Oil
Dennis Isaacs	DuPont
Steve Knis	Dow Chemical
Alan Krol	Amoco
John Kush	Houston Lighting and Power
Carole Lenz	HC PCT 3
Gene McMullen	City of Houston
Mike Magee	Texas Natural Resource Conservation Commission
Fred Manhart	Entergy Services, Inc.
Mark Matteson	Houston Galveston Area Council
Quang Nguyen	EPA Region 6
Edmund Petry	Metro-Houston
Mike Peters	Huntsman Chemical
Chris Rabideau	Texaco Research
Neal Ritchey	Amoco
Charles Schleyer	Mobil Research
Gary Scoggin	Amoco
Jim Smith	Texas Natural Resource Conservation Commission
George Talbert	Mobil
Troy Vickers	Amoco
Michael White	Exxon
Mary Ellen Whitworth	City of Houston, Mayor’s Office

e) Overview of COAST Study

It is clear that as the reliability of the modeling increases, the confidence in ozone precursor reduction targets and selected control strategies also increases. The reliability of the modeling increases with the availability of more complete and representative meteorological, air quality, and emissions data for input to the model. To achieve the goal of increasing the reliability of modeling for Southeast Texas, an intensive study, the COAST Study, was conducted during the summer of 1993. This study was conducted as a cooperative effort among the state, EPA, and the regulated community. The data and results from the COAST study formed the basis for the current attainment demonstration modeling.

The major aspects of the study were the collection of air quality and meteorological data from multiple monitoring sites, and the compilation of a much improved EI for the area. COAST monitoring operations were as follows:

- Additional surface ozone (O_3) and NO_x continuous monitors
- Two continuous gas chromatographs to measure and speciate hourly VOC
- Multiple sites to collect hourly canister samples to measure and speciate VOC
- Multiple sites for acoustic sounders and radar profilers to measure wind speed and direction at various heights in the atmosphere
- Aircraft sampling to measure pollutant concentrations in the upper air
- A continuous monitor on top of a tall building in downtown Houston to measure O_3 and NO_x

The EI aspects of the study were as follows:

- ♦ Develop an hourly point source EI for eight episode days for up to 90% of the total point source emissions of NO_x and VOC
- ♦ Develop a bottom-up EI for the top 14 categories of area and non-road mobile sources
- ♦ Compile an episode day-specific, link-based, hourly on-road mobile EI
- ♦ Conduct data analyses to compare the EI with monitored concentrations
- ♦ Survey local vegetative species and biomass densities to develop an area- and episode-specific biogenic EI.

f) Model Selection

The EPA's *Guideline on Air Quality Models, Revised* defines the UAM as the preferred photochemical grid model for use in developing ozone attainment demonstration SIPs. The regulatory version of the UAM is UAM-IV (version 6.20). However, the commission modeling staff chose to use the variable grid version of the UAM, called the UAM-V, because it incorporates several technical enhancements. These enhancements are as follows:

- ♦ A new vertical grid structure which allows higher resolution of vertical atmospheric layers near the surface, and permits more realistic treatment of nighttime vertical structures and elevated plumes.
- ♦ Three-dimensional inputs - Various meteorological parameters are allowed to vary temporally and spatially instead of being constant over space as in UAM version IV.

- ♦ The ability for the modeling domain to be defined with variable-sized grid cells. This “nested grid” feature allows the use of relatively small grid cells in domain areas where a detailed representation of meteorology, chemistry, and emissions is especially important to the modeling results. It allows the use of larger grid cells where detailed computations and results are not as important. Because variable grid cell sizing allows the use of larger cell sizes in outlying areas than in the critical areas of interest, computation time is reduced, and the use of a larger modeling domain is thus feasible. The use of a larger domain in turn helps minimize the influence of boundary conditions (pollutant concentrations along the outer edges of the modeling domain which can strongly influence the model results, but which may not be well-quantified).
- ♦ Plume in grid - Emissions from elevated stacks can be treated as plumes which disperse slowly, rather than immediately being released into the model’s grid cells.
- ♦ Improved isoprene chemistry - Isoprene is a highly reactive VOC emitted primarily by trees. The latest release of UAM-V, version 1.24, includes improved isoprene chemistry algorithms, which are more appropriate for state-of-the-science biogenic emissions inventories (such as that developed for COAST) than are the analogous algorithms of UAM-IV.

In January 1995, commission staff and representatives from the Technical Oversight Committee met with staff of EPA Region 6 and EPA Headquarters, and obtained approval to use UAM-V provided that the commission conduct and present a favorable comparison of the performance of UAM-V with UAM-IV. For the use of UAM-V to be acceptable, the commission was required to demonstrate that model performance with UAM-V was as good or better than the performance with UAM-IV, the regulatory version. The commission modeling staff conducted the model comparison study as required, and found that UAM-V performance was better than that of UAM-IV for the ozone episode being modeled for this attainment demonstration. Thus, UAM-V was found to be acceptable for this application. Specific procedures and results for the model performance comparison study are found in a later section of this document.

g) Modeling Domain

The UAM domain for the attainment demonstration is represented in both the horizontal and vertical dimensions, and consists of a "small" and "large" domain, as shown in Figure 3. The small domain was designed to encompass the area of most interest for this attainment demonstration (Houston/Galveston) although it also includes the Beaumont/Port Arthur area due to the potential for pollutant transport between the two areas. The grid cell size for the small domain was selected to be relatively small (4 km x 4 km) since model results are more precise with small grid cell sizes, and since the small domain contains the areas of most interest where modeling precision is most important. The large domain includes the Corpus Christi, Victoria, and Lake Charles, Louisiana areas, as well as offshore oil-producing areas, in order to account for the potential impact of emissions from these areas on the Houston/Galveston area. Due to the distance of these other areas from the Houston/Galveston area, the grid cell size in the large domain was selected to be relatively coarse (16 km x 16 km).

The number of vertical layers in a modeling domain is a compromise between including enough detail to accurately characterize the vertical layering of the atmosphere and managing the amount of computer time required to run the model. Eight vertical layers were selected for use in this modeling. The top of the modeling domain was set at 3,000 meters to ensure proper representation of the mixing layer.

Figure 3 COAST Project Modeling Domain

h) Boundary Conditions

Boundary conditions consist of values of air quality parameters at the boundaries of the modeling domain which, through physical and chemical processes, can have a significant influence on ozone concentrations in the areas of interest within the modeling domain. The “large” modeling domain was selected to be sufficiently large to help minimize model sensitivity to boundary conditions.

Boundary condition values are input to the model by the model user. For the Houston/Galveston modeling, boundary conditions were derived from regional modeling conducted by the commission with contract assistance from Environ, Inc. The regional modeling covered a 4-week period in late summer 1993 encompassing the COAST Study period, and including three of the four ozone episodes considered for the attainment demonstration modeling (see subsection on “Episode Selection”). The regional modeling was conducted over a domain stretching from around San Angelo on the west to the Georgia-Alabama border on the east, and from south of Brownsville on the south to the Oklahoma-Kansas border on the north. UAM-V was used for the modeling, with an EI based on the OTAG inventory, and meteorological fields developed with the Regional Atmospheric Modeling System (RAMS).

i) Meteorological and Air Quality Data

The following subsections describe sources of meteorological and air quality data utilized in the Houston/Galveston attainment demonstration modeling.

(1) Surface Measurements

The commission routinely measures meteorological parameters, O_3 and NO_x concentrations at a number of continuous monitoring sites in Harris, Jefferson, Orange, and Galveston counties. The City of Houston measures various meteorological parameters, ozone and NO_x concentrations at seven sites. In addition, meteorological data are routinely collected at four surface monitors located in Victoria County, and two surface monitors located in Corpus Christi.

During the COAST study, the routine monitoring network was complemented by several industry supported networks, including the Houston Regional Monitoring network, the Texas City/La Marque network and the South East Texas Regional Planning Commission network. The commission added two continuous gas chromatographs to measure VOC concentrations at two of the Houston sites specifically for the COAST study. Data was also collected concurrently with COAST during the U.S. Department of the Interior Minerals Management Service project called the Gulf of Mexico Air Quality Study (GMAQS). All monitoring performed in the area followed the measurement and quality assurance procedures defined by the EPA.

The National Weather Service (NWS) also collects surface meteorological data and meteorological observations at many stations in the modeling domain, including Houston Intercontinental Airport. However, given the difficulty of incorporating the 5-minute NWS data into the hourly UAM modeling, this data was used only for data-sparse areas when no other data was available from nearby continuous monitors.

(2) Upper Air Measurements

The NWS takes twice-daily upper air soundings at two sites near the nonattainment area, Corpus Christi, Texas and Lake Charles, Louisiana. During the COAST study, acoustic sounders and radar profilers coupled with radio acoustic sounding systems were used to supplement the NWS vertical profiles. The sounders measured wind direction and velocity at various elevations from 60 meters to 2000 meters at five sites onshore and two sites offshore.

(3) Aircraft Measurements

As a part of the COAST and GMAQS studies, aircraft were used to obtain continuous measurements of O_3 and NO_x concentrations and to collect a limited number of canister samples for analysis of VOC and carbonyl concentrations. The aircraft flew predetermined routes and spirals on forecast high ozone days.

A more detailed description of the meteorological and air quality data used in the attainment demonstration modeling is available in Appendix A, Chapter 3, *Sources of Air Quality Data*, and Appendix A, Chapter 4, *Sources of Meteorological Data*.

j) Modeling Episode Selection

(1) Overview

The EPA, in its "Guideline for Regulatory Application of the Urban Airshed Model" (EPA, 1991), establishes an approach for ozone episode selection that includes identifying meteorological regimes associated with recent high ozone events and ranking them according to the magnitude of the observed ozone.

EPA recommends that candidate episodes have high ozone generally approximating the design value of the city being modeled. EPA also recommends selecting at least three episode days with different meteorological patterns. The “Guideline” also acknowledges that data quality and availability are extremely important considerations in episode selection. The set of robust, quality assured COAST data addressed this consideration. All the candidate episodes for the current attainment demonstration modeling occurred either during the COAST study or during other similar studies.

The following types of ozone episodes were considered:

- ♦ Episodes that occurred during the COAST study or that were supported by other robust data sets.
- ♦ Episodes with relatively high monitored ozone, approximating the Houston/Galveston ozone design value of 220 parts per billion (ppb).
- ♦ Episodes with meteorological regimes (wind flow patterns) typical of high ozone events.

Since several of the candidate episodes met the above criteria, the following additional criteria were also considered:

- ♦ One episode day should illustrate ozone formation associated with relatively light winds (stagnant meteorological conditions), indicating local production of ozone, and;
- ♦ One episode should illustrate ozone formation associated with well defined wind flow (good ventilation), indicating meteorological transport of ozone and precursors.

Following the EPA recommendations, episode selection was made by a team, including meteorologists who were familiar with the local and regional meteorological patterns occurring along the Texas Gulf Coast. The team screened the candidate episodes for the availability of comprehensive data sets, and favored episode days with monitored ozone approximating the Houston/Galveston ozone design value.

(2) Additional Considerations

The Gulf of Mexico Air Quality Study established that high ozone events along the Gulf Coast are frequently associated with a land/sea breeze wind reversal. Therefore, the effect of both morning and afternoon wind speed and directions was considered in defining the meteorological patterns associated with high ozone events. However, given the primary concerns for enhanced data availability and high monitored ozone, meteorological regime analysis was used only to confirm that the selected episodes were generally representative of high ozone events.

In the Houston/Galveston area, most episodes are multi-day, some being as long as eight days. Therefore, extended episodes were favored over short episodes. Selecting longer episodes provided additional benefits later on in the process by allowing model performance statistics to be calculated over several days. This provided additional assurance that the UAM was delivering consistent performance. Finally, given the short period of the COAST study and the need to maximize usage of the available data, episode selection included consideration of Beaumont/Port Arthur ozone occurrences so that selected episodes would be useful for modeling work related to both nonattainment areas.

(3) Candidate Episodes

In total, seven episodes with high ozone and robust data sets were identified as candidates for the current attainment demonstration modeling. Five identified potential episodes occurred during the intensive monitoring period of the COAST study. For these episodes, monitored ozone concentrations exceeded the standard at several sites and the maximum ozone concentration exceeded 160 ppb somewhere in the Houston/Galveston area.

Two additional candidate episodes occurred before the COAST study during October 1992, a time period when routine air quality and meteorological monitoring was enhanced with additional surface monitoring, acoustic sodars on Galveston Island and at Jefferson County Airport, and a radar profiler located in the Houston/Galveston area.

Table 3 lists all candidate COAST-period and 1992 study episodes. The episodes chosen for modeling were selected from this list.

Table 3. Candidate Episodes for UAM Modeling						
Episode Dates	Maximum 1-hour Ozone Concentrations in ppb					
	Houston/Galveston			Beaumont/Port Arthur		
	Date	O_3	Site	Date	Ozone	Site
July 29-31, 1993	July 30	183	Seabrook	No Exceedances		
August 10-11, 1993	August 10	172	Galleria	No Exceedances		
August 18-20, 1993	August 19	231	Aldine	August 19	125	Sabine
September 1-2, 1993	September 1	164	HRM 11	September 2	139	Sabine
September 8-11,	September 8	214	Smith Pt.	September 10	141	Sabine
October 4-5, 1992	October 4	229	HRM 03	October 5	137	Jefferson
October 24-25, 1992	October 24	198	Galveston	October 25	137	W. Orange

*Sometimes, depending on the context, this episode is referred to as September 6-11, 1993. Although the ozone episode occurred from September 8-11, 1993, modeling typically starts one to two days earlier to study the conditions on the days leading up to the ozone episode. These days are known as "ramp-up days."

Of the seven candidate episodes with robust data sets, two were eliminated from further consideration as Houston/Galveston episodes (September 1-2, 1993 and October 4-5, 1992) because they had wind patterns less frequently associated with high ozone than the other candidate episodes. The July 29-31, 1993 episode had wind patterns frequently conducive to high ozone, but was eliminated because four other episodes included similar wind directions but higher ozone (August 10-11, 1993; August 18-20, 1993; September 8-11, 1993; and October 24-25, 1992). The October 24-25, 1992 was only 2 days long and had lower ozone than the other three episodes mentioned above. The August 10-11, 1993 episode was only two days long and had lower ozone concentrations than the August 18-20, 1993 and September 8-11, 1993 episodes.

Of the five episodes having wind patterns typically associated with high ozone, then, the August 18-20, 1993 and the September 8-11, 1993 episodes were preferred because they had representative wind patterns, higher ozone, and more episode days compared to the other episodes. These two episodes satisfy the EPA episode selection recommendations by providing at least three high episode days with typical wind patterns. These two episodes also include the five highest daily maximum ozone concentrations measured during the COAST study. The two selected episodes are discussed in more detail below.

Two additional episodes listed in Table 3 were also modeled during the COAST study, but were primarily selected for studying ozone formation and transport affecting the Beaumont/Port Arthur nonattainment area. These episodes are September 1-2, 1993, and October 24-25, 1992. Since these episodes were not of primary interest for the Houston/Galveston area, they are not discussed in detail here, but are mentioned in subsequent sections of this report, and are discussed extensively in the appendices.

August 18-20, 1993

The August 18-20, 1993 episode had the highest monitored ozone concentration (231 ppb on August 19th) of any of the episodes under consideration. Furthermore, the 231 ppb ozone concentration at Aldine in the Houston/Galveston domain was slightly greater than the Houston design value of 220 ppb.

This 3-day episode included two days having wind patterns typically associated with high ozone in the Houston/Galveston area (August 18, 1993 and August 20, 1993), and a third with wind patterns close to those typically associated with high ozone (August 19, 1993). The ozone standard was exceeded at eight Houston/Galveston monitors on the 19th and 20th, comprising a relatively large number of exceedances compared to the other episodes during the COAST study. In addition, since this episode occurred during the COAST study, the study area was exceptionally well-instrumented. Finally, this episode had been previously selected and modeled as part of the GMAQS study, which enabled the commission to perform a quality assurance cross check of the meteorological input files.

September 8-11, 1993

The September 8-11, 1993 episode included two days (8th and 11th) having wind patterns typically associated with high ozone in the Houston/Galveston area, and a third day with wind patterns close to those typical of high ozone conditions. The second highest ozone concentration (214 ppb on September 8th at Smith Point) measured during the COAST study was recorded during this episode. This single episode provided an opportunity to model four consecutive days of ozone exceedances in the Houston/Galveston area. On three of the days, the highest ozone occurred in coastal areas, while on the fourth, the highest ozone occurred in the Houston area proper.

Although the intensive monitoring period of the COAST study ended August 28, 1993, additional data was available because enhanced monitoring was continued at many monitoring sites in the area until the end of October 1993. This episode had also been modeled as part of the GMAQS study, which provided the opportunity to cross check the commission meteorological modeling.

A more detailed description of the candidate episodes for the COAST modeling is available in Appendix A, Chapter 2, *Meteorological Modeling and Air Quality*.

(4) Meteorological Description of Selected Episodes

August 18-20, 1993

The August 18-20, 1993 episode was characterized by a typical Gulf Coast summer weather pattern. During the days prior to the episode, high pressure extended from the Gulf to the southern portion of the United States producing large scale south to westerly winds in the Houston/Galveston area. Beginning on the 17th, the high pressure weakened and shifted northwestward to the upper Texas coast. Under these conditions smaller scale local heating and cooling effects began to influence the wind flow, so nocturnal land breezes and daytime bay/sea breezes could form. The resultant daily land/sea breeze flow reversal pattern repeated for all three days of the episode, penetrating far inland.

Wind trajectories showed that during the morning hours of the episode days, air parcels moved from near Houston over Galveston Bay toward the Gulf. The flow reversed and returned from Galveston Bay to the Houston area in the early afternoon.

September 8-11, 1993

The September 8-11, 1993 episode was characterized by a late summer transitional weather pattern. During the two days prior to the episode, the first weak cold front of the autumn season moved into the Gulf, resulting in northeasterly flow across the Texas coast. By September 8th, the offshore frontal boundary weakened, resulting in weaker winds in the area. The weaker wind field allowed nocturnal land breezes and daytime bay/sea breezes to form. During the early morning hours of September 8th, the land breeze moved towards the coast, and by noon the sea breeze was evident at Galveston and moved inland. However, the light northwesterly flow delayed the sea breeze over Galveston Bay until evening.

By September 9th, another weak front moved into the area and became stationary between Houston/Galveston and Beaumont/Port Arthur. The high pressure behind the front reinforced the northwest land breeze and again retarded the sea breeze, which was observed at the coast but was not able to move very far inland. By the 10th, this front had weakened and somewhat more typical land/sea breeze patterns resumed on the 10th and 11th.

Wind trajectories showed that during the morning hours, air parcels moved from near Houston over Galveston Bay toward the Gulf. Although a weak flow reversal developed during the middays, the sea breeze did not penetrate very far inland on any of the episode days.

k) Meteorological Model Selection

The UAM requires meteorological information to characterize pollutant transport and mixing in the atmosphere. Meteorological information is also involved to some extent in the model's chemistry.

In the past, the EPA has recommended use of diagnostic models which simply interpolate and smooth the available meteorological data. However, it is not possible to represent the complex meteorological variations in the Gulf Coast area (e.g, the coastal land-sea breeze) using a smoothing model. On the other hand, prognostic models can calculate meteorological variables based upon the physical principles and meteorological forces involved such as temperature and pressure differences. Prognostic models can be used to estimate the winds and mixing for areas with little data. This makes prognostic models particularly useful for large modeling domains, which have large data-sparse areas at higher levels of the atmosphere and locations far away from monitors.

For the attainment demonstration modeling the commission elected to use an improved prognostic meteorological model to represent the wind speed, direction and vertical mixing parameters required by the newest version of the UAM, UAM-V. The SAIMM (Systems Applications International Meteorological Model) has several advantages over previous prognostic and diagnostic models in the way it assimilates the observed meteorological data and incorporates it into the mathematics of the model. The SAIMM also produces the various meteorological data fields in the format required by the UAM-V. Additional technical details on this model and the use of the model to produce meteorological fields are available in Appendix A, Chapter 5, *Meteorological Model Selection;* Appendix A, Chapter 6, *SAIMM Preparation and Post-Processing;* Appendix A, Chapter 7, *August 16-20, 1993 Episode*; and Appendix A, Chapter 8, *September 6-11, 1993 Episode*.

l) Base Case EI Development

Two major types of inventories were developed for the attainment demonstration modeling: a modeling inventory for "base case" ozone episodes, upon which a model performance assessment was based; and a projected modeling inventory for the attainment year (2007), upon which the attainment demonstration was based. For each type of inventory, emissions data were developed for several categories of emission sources.

Base case inventory development for the various source categories is discussed below. Additional information on base case emissions is provided in Appendix B, Chapter 1, *Introduction and Emissions Summary,* and in other report chapters referenced in the following sections. Future year inventory development is discussed in later sections of this document.

A modeling EI is composed of point, on-road mobile, area, non-road mobile, and biogenic emissions. Texas developed a 1993 periodic EI which followed the prescription of the 1990 FCAA Amendments EI, but which reflected conditions in 1993. This 1993 EI was used as the base inventory from which an episode-specific inventory was developed. Where possible, emissions were adjusted for any pertinent conditions related to each episode day.

As indicated earlier, there were several components of the COAST study that related to EI development. The role of these components will be discussed in the following sections relating to each source type.

(1) Source Types

Point Sources

Point source emissions include emissions from storage tanks, fugitives (e.g., leaking pipes), large coating operations, engines, boilers, and many large scale industrial processes. As part of the COAST Study, episode-day and hour-specific point source emissions from the ozone episode covering the period August 17 to 21, 1993 were obtained by surveying the largest sources in the Houston/Galveston, Beaumont/Port Arthur, and Lake Charles areas. Adjustments were made to account for meteorological conditions, operating conditions, upsets, start-ups, and shut-downs. Because many of the factors that comprise the concept of rule effectiveness were directly accounted for in the survey, no rule effectiveness adjustments were applied to emissions reported in the survey. Respondents to the survey accounted for 98% of the VOC and 96% of the NO_x point source emissions in the nonattainment areas within the modeling domain. In cases where the surveys contained no usable information about a source, the ozone-season daily emissions, adjusted for rule-effectiveness, were used. For other ozone episodes occurring during the COAST Study, the hourly emissions for August 17 to 21 were used where they were judged to be typical (except for electric utilities, which supplied daily emissions for all episode days). In cases where it was clear that the emissions reported in the survey were specific only to the August 17 to 21, 1993 time period, the 1993 EI base values were used for other episodes.

Many companies supplied daily and even hourly chemical speciation profiles as part of the COAST survey. When available, these data were used to develop the Carbon-Bond IV (CB-IV) speciation profiles used in UAM. For other sources, chemical speciation profiles were based on source-specific data in the commission's Point Source Data Base. In cases where no source-specific data were available, EPA default speciation profiles were used. Finally, in cases where only partial speciation was available, the EPA default profiles were used to complete the speciation of these sources.

The detailed process for the development of the point source modeling inventory is provided in Appendix B, Chapter 2, *Point Source Emissions*.

On-road Mobile Sources

On-road mobile source emissions are generated by automobiles and other vehicles traveling along roadways. They include startup, hot soak (fuel evaporation after shutoff), exhaust, running losses (fuel evaporation while running), and diurnal fuel evaporation caused by the daily cycle of heating and cooling of the gas tank. Both NO_x and VOC emissions vary from day to day and from hour to hour in response to traffic, but VOC emissions are also very sensitive to ambient temperature.

One part of the COAST study was the development of an episode-specific, link-based on-road mobile source EI. For the 11 counties comprising the Houston/Galveston and Beaumont/Port Arthur nonattainment areas, and Victoria County, a traffic demand model was run using traffic data collected during the study period to determine vehicle miles traveled (VMT) and average vehicle speed for various roadway network links. The period August 17 to 21, 1993 was modeled explicitly in the nonattainment counties. Traffic surveys conducted during the summer of 1993 were used to establish the VMT mix and hourly VMT fractions. Hourly speeds were calculated for each roadway link using a speed model. Then, MOBILE5a emission factors were used to determine hourly emissions by link for each vehicle class. Hourly temperatures for each day modeled were used as input to MOBILE5a. Finally, the link-based hourly emissions were gridded using a geographic information system. Emissions for other episode days were derived from the August 17 to 21 period by applying factors based on MOBILE5a runs using episode day-specific temperatures. All emissions were adjusted a final time to account for differences between the travel-demand model and the Highway Performance Monitoring System (HPMS) estimates of VMT.

On-road mobile source emissions for all other counties were developed using HPMS VMT and episode day-specific minimum and maximum temperatures. Emissions for major highways were allocated to roadway links, while emissions from minor roads and city streets were allocated spatially to the population surrogate.

The detailed process for the development of the on-road mobile source EI is provided in Appendix B, Chapter 3, *On-road Mobile Source Emissions*.

Area and Non-road Mobile Sources

Area and non-road mobile source emissions emanate from commercial, small industrial, and residential sources that are too numerous to inventory separately. Area source emissions include evaporative emissions; e.g., solvents and coatings (paints), as well as emissions from non-road engines such as lawn mowers, generators, forklifts, tractors, construction equipment, aircraft, boats, railroad engines and similar equipment that does not travel on roads.

County-wide area source emissions from the 1993 periodic EI, including non-road mobile sources, were calculated using standard emission factors, and allocated to modeling domain grid squares based on surrogates that represent the distribution of these sources over the area. One of the COAST component projects was the development of a bottom-up inventory for 11 area and non-road mobile source categories. Information collected during this survey, and subsequently by commission EI staff, were used where applicable.

Offshore area and non-road mobile source emissions obtained from the Gulf of Mexico Air Quality Study were used for the offshore areas of the modeling domain.

A number of spatial surrogates were developed by commission staff and the bottom-up EI contractor to better allocate certain area and non-road mobile source categories (e.g. oil and gas fields, gasoline stations, agriculture). Also, several link files were developed to spatially allocate link-based emissions such as shipping and locomotive emissions.

It should be noted that for some modeling applications, automotive refueling emissions are estimated using the EPA's mobile source emissions model MOBILE5a, and are then included in the *on-road* mobile source emissions. The commission staff instead chose to estimate refueling emissions based on county fuel sales, and then treated them as area sources. This allowed the refueling emissions to be spatially located at service stations instead of distributed along the roadways.

The detailed process for the development of the area and non-road mobile source EI is provided in Appendix B, Chapter 4, *Area and Off-road Mobile Source Emissions*.

Biogenic Sources

Biogenic emissions are generated by both naturally occurring and cultivated plants, primarily trees, which are assessed from land-use data, satellite imagery, and biological surveys. Biogenic emissions are quite variable because they are highly sensitive to variations in sunlight and temperature. For example, in one of the candidate ozone modeling episodes (October 24-25, 1992), biogenic emissions were estimated to be much lower than during the other candidate episodes, partly because of 10-15 degree Fahrenheit lower temperatures and partly because of reduced sunlight. While biogenic emissions are typically highest in rural areas, there are significant amounts of vegetation, hence biogenic emissions, in urban areas.

Emissions from biogenic sources were estimated using the Emissions Modeling System 95 (EMS-95) biogenic emissions processor. This processor was used instead of EPA's Biogenic Emissions Inventory System (BEIS) or the newer BEIS-2 because of its ability to easily incorporate locally-developed biomass and emission-factor data. As part of the COAST Study, a contractor surveyed the COAST domain and developed biomass density estimates based on land use/land cover (LULC) categories. The contractor also compiled the best available emission factor data for those species found in the COAST domain. The EMS-95 biogenic emission estimation software accepts these local data, along with gridded hourly temperature and solar radiation data, and produces hourly gridded emissions.

The detailed process for the development of the area source EI is provided in Appendix B, Chapter 5, *Biogenic Emissions Estimates*.

(2) Level of Emissions

In this section, the VOC and NO_x modeling EI developed for the attainment demonstration is summarized. First, emissions for the entire COAST modeling domain are summarized for all four COAST ozone episodes, including two episodes primarily selected for Beaumont/Port Arthur. (Even though only one episode, September 6-11, 1993, ultimately was used in the attainment demonstration, it is informative to include emissions from all four COAST episodes to illustrate the variability of the emissions.) Then, emissions from two nonattainment counties of significant interest (Harris County and Jefferson County) are presented for the episodes. Finally, example tileplots are provided which show the spatial and temporal distribution of emissions for one COAST episode day. Other information, including summary tables and graphs for other nonattainment counties, is provided in Appendix A, Chapter 1, *Introduction and Emissions Summary*.

Domain Total NO_x Emissions

Table 4 shows the COAST domain total daily emissions of NO_x by class for each of the COAST ozone episodes. Point source emissions dominate the NO_x emissions on every day. Since these emissions are mostly from industrial facilities that operate constantly year round, there is little variation from day to day. Emissions were slightly higher in the August 17-21, 1993 episode than during the other episodes, primarily due to increased electric generation on these very hot days.

Mobile source NO_x emissions are much lower in magnitude than the point sources, but they vary significantly from day to day, due mostly to increased vehicle use on Friday followed by a reduction in vehicle use on weekends in the urban areas. Emissions for the October 23-25, 1992 episode show a variation resulting from an adjustment for differences in year and season.

Area source NO_x emissions are third in magnitude, and exhibit some day-to-day variation. Most area source NO_x emissions are generated by off-road vehicles (including boats). Commercial and industrial use of off-road equipment drops significantly on weekends. However, this reduction is countered in large part by increased use of boats, lawn mowers, and related equipment.

Biogenic sources contribute a relatively small fraction of total NO_x emissions in the modeling domain. The day-to-day variation seen in biogenic NO_x emissions is due to differences in temperature and solar radiation.

Table 4. COAST Total NO_x Emissions by Emission Class

tons / day

Date	Day	Area	Biogenic	Point	Mobile	Total
10/23	Fri	591	85	1,516	886	3,079
10/24	Sat	544	87	1,506	661	2,799
10/25	Sun	486	93	1,515	572	2,667
08/16	Mon	608	128	1,620	768	3,124
08/17	Tues	608	129	1,638	768	3,142
08/18	Wed	608	127	1,620	768	3,123
08/19	Thurs	608	127	1,612	768	3,115

08/20	Fri	608	125	1,612	851	3,196
08/21	Sat	561	123	1,593	630	2,907
08/31	Tues	591	117	1,530	770	3,008
09/01	Wed	591	119	1,556	769	3,034
09/02	Thurs	591	124	1,562	769	3,046
09/06	Mon	501	112	1,514	768	2,895
09/07	Tues	501	118	1,543	767	2,929
09/08	Wed	501	114	1,549	768	2,931
09/09	Thurs	501	114	1,540	768	2,923
09/10	Fri	501	119	1,563	867	3,050
09/11	Sat	467	112	1,561	638	2,778

Domain Total VOC Emissions

Table 5 shows the domain total daily emissions of VOC by class for each of the COAST episodes.

Despite daily and seasonal variations, biogenic VOC emissions always dominate the domain total VOC emissions on ozone episode days. However, biogenic emissions are located mostly in rural areas, which may limit their impact on ozone formation.

On weekends, area sources are the largest category of anthropogenic (man made) VOC emissions. These emissions are significantly greater on weekends than weekdays because of increased outdoor activities, including lawn mowing and recreational boating. However, weekend area source emissions (primarily boating) tend to be more spread out spatially than workweek emissions, so may have relatively less impact on ozone formation than workweek emissions.

Point source VOC emissions, which include fugitive losses (e.g. leaking pipes), storage tank losses, refinery, and fuel combustion emissions are about equal to area source emissions. However, point source emissions are relatively constant, while area sources increase from weekday to weekend. So, point source emissions are larger on weekdays, while area source emissions are larger on weekends. While both total point and area source VOC emissions are much smaller than the total biogenic VOC emissions, they tend to be concentrated in industrial areas near population centers, and may have a greater impact on ozone formation in such areas than the biogenic emissions.

Mobile source VOC emissions are the smallest class of VOC emissions, but like point sources, tend to be released primarily in heavily populated areas, so they may also contribute significantly to ozone formation.

Table 5. COAST Total VOC Emissions by Emission Class						
tons / day						
Date	Day	Area	Biogenic	Point	Mobile	Total
10/23	Fri	800	4,226	823	409	6,258
10/24	Sat	968	4,687	809	335	6,799
10/25	Sun	865	5,413	805	306	7,389
08/16	Mon	780	9,658	783	434	11,655
08/17	Tues	780	9,741	798	434	11,752
08/18	Wed	780	9,625	788	433	11,625
08/19	Thurs	780	9,583	788	433	11,584
08/20	Fri	780	9,114	777	473	11,144
08/21	Sat	969	8,234	770	373	10,345
08/31	Tues	779	7,615	783	418	9,595
09/01	Wed	782	8,410	783	429	10,404
09/02	Thurs	796	8,973	783	429	10,981
09/06	Mon	767	7,334	783	404	9,288
09/07	Tues	763	8,380	783	409	10,336
09/08	Wed	767	8,496	783	410	10,456
09/09	Thurs	780	7,249	783	402	9,214
09/10	Fri	784	8,292	783	460	10,318
09/11	Sat	1,083	7,307	768	358	9,516

Distribution of Total Emissions in Time and Space

Figures 4 and 5 are example tile plots and related plots showing the spatial and temporal distribution of total NO_x and VOC (represented as CB-IV HC[1]) emissions. The plots are shown for August 19, 1993, the day having the highest ozone during the COAST episodes. Although we have selected another episode for the attainment demonstration modeling, the tile plots for August 19, 1993 are illustrative of spatial and temporal emissions distributions for the COAST domain.

As shown in Figure 4, NO_x emissions are widely distributed over the entire modeling domain, with high concentrations in urban areas. Urban NO_x emissions are predominately generated by mobile sources, both on-and off-road. Several large electric generation facilities, such as the Parish Power Plant (shown on the figure) dot the rural areas. Large industrial complexes in Freeport, Corpus Christi, Texas City, Beaumont, Port Arthur, Lake Charles, and along the Houston Ship Channel are clearly visible. Transportation sources, such as Houston Intercontinental Airport, automobiles, and shipping contribute to the mix. Emissions along several major highways and part of the Gulf Intracoastal Waterway are visible on the map. Finally, significant amounts of NO_x in the Gulf of Mexico are generated by offshore oil and gas production facilities.

Overall, significant levels of NO_x are produced 24 hours a day, as shown on the inset line graph labeled "Diurnal Profile" in Figure 4, primarily because of continuous operations at large industrial facilities. For example, electric generation facilities reduce operations, but still produce large quantities of NO_x

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[1]The UAM represents atmospheric chemical reactions using a simplified chemical mechanism called Carbon Bond IV (CB-IV). The CB-IV mechanism converts VOCs into idealized compounds, characterized by the structure of the molecular bonds among carbon atoms, called CB-IV hydrocarbons, or CB-IV HC. As mass of actual VOC is converted to CB-IV HC, some mass is invariably gained or lost; however, the CB-IV mass generally differs from the actual VOC mass by only a few percent.

during the night. During daylight hours, total NO_x production increases because of both on- and off-road mobile sources. While on-road mobile source emissions peak during both the morning and evening rush hours, off-road mobile sources are concentrated during daytime working hours and largely fill the valley between the two on-road peaks on the graph.

Figure 4 NO_x tileplots

Figure 5 VOC tileplots

Figure 5 shows that significant CB-IV HC (VOC) emissions occur nearly everywhere except in the Gulf of Mexico. This is caused by biogenic sources, which are most prominent in the piney woods of East Texas and Louisiana. On-road mobile and area sources combine to add significantly higher concentrations in the urban areas of the domain, and point sources in Freeport, Corpus Christi, Texas City, Beaumont, Port Arthur, Lake Charles, and along the Houston Ship Channel are seen to produce very high VOC emissions in relatively confined areas. Because the day shown (August 19, 1993) is a weekday, pleasure boating activity is relatively low; however, on Saturdays and Sundays, significantly higher VOC emissions are seen in Galveston Bay, Sabine Lake, and several freshwater lakes in the area.

The diurnal emissions profile seen in the inset in Figure 5 is dominated by biogenic emissions, which peak during mid-afternoon. A significant portion of the overnight VOC emissions is contributed by petroleum refining and petrochemical facilities, with some contribution from area, mobile and biogenic sources.

Tileplots of total domain emissions for each emission category (point, on-road mobile, area and non-road mobile, and biogenics) are provided in Appendix B, Chapter 1, *Introduction and Emissions Summary*.

Emissions for Selected Counties

In this section, Harris and Jefferson County emissions are discussed in detail. Harris County, which contains the City of Houston, is responsible for the vast majority of emissions in the Houston/Galveston nonattainment area. This county is of particular interest since the attainment demonstration is focused on the Houston/Galveston area. Similarly, Jefferson County, which contains the cities of Beaumont and

Port Arthur, generates most of the emissions in the Beaumont/Port Arthur nonattainment area. As noted previously, the Beaumont/Port Arthur area is within the COAST modeling domain and is of interest due to the potential transport between the two nonattainment areas.

Emissions information for the other nonattainment counties in the COAST domain is provided in Appendix B, Chapter 1, *Introduction and Emissions Summary*.

Harris County NO_x Emissions

Harris County total NO_x emissions by class are shown in Table 6. The point source and mobile source NO_x emissions for the county are roughly equal, so the one which is largest varies from day to day. While the point source NO_x emissions are relatively constant, the mobile source NO_x emissions vary significantly from day to day in response to changing traffic patterns and temperature.

Area source NO_x emissions, which include both commercial and recreational marine vessel emissions, are a distant third in magnitude. While area sources include recreational boating and lawn equipment emissions, which increase on weekends, they also include construction equipment emissions, which decrease on weekends. In Harris County, this results in a net reduction of area source emissions on weekends, but some other counties experience a net increase on the weekend.

Note that in highly urbanized Harris County, biogenic NO_x emissions are insignificant.

Table 6. Harris County Total NO_x Emissions						
tons / day						
Date	**Day**	**Area**	**Biogenic**	**Point**	**Mobile**	**Total**
10/23/92	Fri	163	3	302	360	829
10/24/92	Sat	131	3	311	228	673
10/25/92	Sun	99	3	306	182	590
08/16/93	Mon	163	4	318	312	797
08/17/93	Tues	163	4	319	312	798
08/18/93	Wed	163	4	319	312	798
08/19/93	Thur	163	4	317	313	797
08/20/93	Fri	163	4	315	341	823
08/21/93	Sat	131	4	312	222	670
08/31/93	Tues	163	4	299	314	780
09/01/93	Wed	163	4	309	313	789
09/02/93	Thur	163	4	313	313	793
09/06/93	Mon	149	4	280	311	744
09/07/93	Tues	149	4	295	310	758
09/08/93	Wed	149	4	305	310	768
09/09/93	Thur	149	4	292	311	756
09/10/93	Fri	149	4	314	350	817
09/11/93	Sat	118	4	299	226	647

Harris County VOC Emissions

Table 7 shows Harris County VOC emissions by day and class.

On most episode days, the largest class of VOC emissions in Harris County are biogenic emissions, which at first glance may be surprising. However, Harris County is quite large, and many rural areas of the county are heavily wooded. Even in highly developed residential areas, the warm temperatures and abundant rainfall help residents maintain a bountiful crop of trees. However, in the October 23-25, 1992 episode, biogenic VOC emissions are much smaller than in the other episodes, due to the fall season's lower temperatures and reduced sunlight.

Point sources are the second largest source of VOCs, except during the October 23-25, 1992 episode, when they are the largest. This abundance of point source VOC emissions is typical of the highly industrialized Gulf Coast region, but unusual compared to other urban areas around the country. While area and mobile sources dominate anthropogenic VOC emissions in most areas of the country, Harris County contains numerous large petroleum loading, storage, and refining facilities, as well as numerous petrochemical plants, all of which contribute to the point source VOC emissions total.

Close behind point sources, area sources contribute a large fraction of the Harris County VOC emissions. The significant reductions seen in this category on weekends are due primarily to commercial sources, which are assumed to have lower activity levels on Saturday, and particularly on Sunday. The increased boating activity which boosts the domain total area source emissions on weekends does not apply to Harris County, since the county has little water surface area suitable for recreational boating.

The smallest class of VOC emissions in Harris County is mobile sources. These emissions vary greatly from day to day in response to traffic and temperature variations. The primary reason the mobile source VOC emissions are so small relative to the other categories is the use of low-volatility gasoline in 1992 and 1993 (Reid Vapor Pressure of 7.2). However, commission staff believe that the mobile source VOC emissions are potentially underestimated, and are actively working to develop improved mobile source emissions modeling methodologies for the entire COAST domain.

Table 7. Harris County Total VOC Emissions						
tons / day						
Date	**Day**	**Area**	**Biogenic**	**Point**	**Mobile**	**Total**
10/23/92	Fri	247	153	267	154	822
10/24/92	Sat	190	184	261	110	744
10/25/92	Sun	151	218	258	97	723
08/16/93	Mon	242	375	253	161	1,031
08/17/93	Tues	242	383	261	161	1,047
08/18/93	Wed	242	371	260	160	1,034
08/19/93	Thur	242	374	255	161	1,032
08/20/93	Fri	242	367	253	173	1,034
08/21/93	Sat	190	328	246	121	885
08/31/93	Tues	242	264	253	150	909
09/01/93	Wed	243	344	253	158	998
09/02/93	Thur	246	350	253	158	1,008
09/06/93	Mon	202	281	253	149	885
09/07/93	Tues	201	322	253	153	929
09/08/93	Wed	202	328	253	153	936
09/09/93	Thur	205	247	253	146	851
09/10/93	Fri	206	322	253	173	955
09/11/93	Sat	152	281	246	118	798

Jefferson County NO_x Emissions

Table 8 shows Jefferson County NO_x emissions by day and class. Point source emissions are the dominant source of NO_x emissions in Jefferson County, accounting for almost two-thirds of the county's total NO_x emissions. However, Jefferson County point source NO_x emissions are only a third of Harris County point source NO_x emissions. Area source NO_x emissions are a distant second in magnitude, followed closely by on-road mobile source emissions. As in Harris county, biogenic NO_x emissions are not significant.

Table 8. Jefferson County Total NO_x Emissions

tons / day

Date	Day	Area	Biogenic	Point	Mobile	Total
10/23/92	Fri	42	2	110	35	189
10/24/92	Sat	38	2	110	23	173
10/25/92	Sun	33	2	110	18	163
08/16/93	Mon	42	2	103	28	176
08/17/93	Tues	42	2	102	28	175
08/18/93	Wed	42	2	104	28	176
08/19/93	Thur	42	2	103	28	176
08/20/93	Fri	42	2	104	33	182
08/21/93	Sat	38	2	104	21	165
08/31/93	Tues	42	2	103	28	175
09/01/93	Wed	42	2	103	28	176
09/02/93	Thur	42	2	103	28	176
09/06/93	Mon	24	2	103	28	157
09/07/93	Tues	24	2	103	28	157
09/08/93	Wed	24	2	103	28	157
09/09/93	Thur	24	2	103	28	157
09/10/93	Fri	24	2	103	35	165
09/11/93	Sat	21	2	104	22	148

Jefferson County VOC Emissions

Table 9 shows Jefferson County VOC emissions by day and class.

Jefferson County VOC emissions are dominated by point sources. The total point source VOC emissions are approximately 60% as large as those located in Harris County. Like Harris County, Jefferson County has a large number of petroleum loading, storage, and refining facilities and petrochemical plants, which contribute to the unusually large fraction of point source VOC emissions.

Jefferson County has a large biogenic VOC component, particularly on the August and September episode days. Next in magnitude are area sources, followed by a relatively small amount of on-road mobile source emissions.

Table 9. Jefferson County Total VOC Emissions						
tons / day						
Date	**Day**	**Area**	**Biogenic**	**Point**	**Mobile**	**Total**
10/23/92	Fri	40	46	165	16	268
10/24/92	Sat	52	51	163	12	277
10/25/92	Sun	47	55	163	10	274
08/16/93	Mon	40	104	142	15	301
08/17/93	Tues	40	106	143	15	305
08/18/93	Wed	40	105	141	15	301
08/19/93	Thur	40	105	143	15	302
08/20/93	Fri	40	97	141	17	295
08/21/93	Sat	52	81	141	12	285
08/31/93	Tues	40	87	142	14	283
09/01/93	Wed	40	99	142	15	295
09/02/93	Thur	40	98	142	15	295
09/06/93	Mon	29	84	142	14	269
09/07/93	Tues	29	90	142	14	276
09/08/93	Wed	29	89	142	14	275
09/09/93	Thur	30	89	142	14	275
09/10/93	Fri	30	92	142	17	282
09/11/93	Sat	37	82	140	12	270

m) Base Case Modeling and Performance Evaluation

(1) Introduction

In addition to the meteorological and emissions data files (discussed in previous sections of this report), a number of other data files are required to run the UAM-V. The first part of this section describes the development of these additional input files, followed by a discussion of modeling the COAST base case episodes. The remainder of the section discusses the evaluation of model performance for two base case episodes, August 18-21, 1993 and September 8-11, 1993.

(2) Model Input Data

Figure 6 provides an overview of the UAM-V input and output files. The development of the meteorological and emissions data files is summarized in the preceding sections of this document, and is described in more detail in Appendices A and B. Brief descriptions of the development of the remaining model input files are provided below.

Figure 6 Overview of UAM-v Input and Output files

Initial and Boundary Conditions Files

As discussed in the Boundary Conditions Overview section of this report, the commission and Environ, Inc. developed a regional model specifically for the purpose of defining boundary conditions for modeling the COAST domain. The results of this regional model were used to produce the lateral and top boundary conditions files and initial conditions files necessary to run the base case model. A detailed description of the regional model development is contained in the Environ, Inc. report entitled *Future-Year Boundary Conditions for Urban Airshed Modeling for the State of Texas (1996),* which is available from the commission upon request.

The initial conditions file is a three-dimensional array of chemical concentrations characterizing air quality at the beginning of the model simulation. In most modeling applications initial conditions are defined directly from measurements at a few monitoring stations in the modeling domain; however these monitors generally do not reflect rural pollutant concentrations and do not measure concentrations aloft. Since the regional modeling covered a 28-day time period spanning the two COAST episodes which were candidates for modeling, the results of this model provide a three-dimensional field of chemical concentrations at the start of each episode (initial conditions).

The lateral boundary conditions file contains hourly chemical concentrations distributed horizontally and vertically along the sides of the modeling domain (the lateral boundaries can be best visualized as four "walls" surrounding the area modeled). This file allows pollutants generated outside the modeling domain to be accounted for in the simulation. The top boundary conditions file is used to define chemical concentrations at the top of the modeling domain (visualized as the "ceiling" of the region modeled) for each hour of the simulation. Chemicals can also enter the modeling domain through this route. Both lateral and top boundary conditions for the relevant COAST episodes were derived from the regional model results.

One of the key sensitivity analyses described in more detail below compares model performance using the regional model-based boundary conditions with model performance using boundary conditions derived from an earlier regional modeling study called the Gulf of Mexico Air Quality Study (GMAQS).

Land Use

The UAM-V requires gridded land-use data for modeling deposition (the removal of airborne chemicals through contact with surface features such as trees). The land use files developed for the UAM-V modeling were developed from the United States Geological Survey (USGS) Land Use/Land Cover (LULC) digital maps. Because the maps covering Southeast Texas are somewhat outdated (developed for the most part in the 1970's), commission staff used LANDSAT satellite images to identify areas in the Houston metropolitan area which had been developed since the LULC maps were produced.

Terrain

The UAM modeling system once required gridded surface elevation data so that altitudes could be specified for the calculation of some radiative processes. UAM-V still requires a terrain file although the data is no longer used.

Photolysis and Reaction Rates

The UAM-V requires a file containing photolysis and chemical reaction rates, which are used in the model's chemistry subroutines. The commission used the latest version of UAM-V (v 1.24) for the modeling, which incorporates improved isoprene chemistry developed as part of the Ozone Transport Assessment Group study. The photolysis and reaction rates used in the modeling were consistent with those developed for OTAG to use with UAM-V 1.24..

Albedo/Haze/Ozone Column File

The photochemistry in the UAM-V is dependent upon the amount of solar radiation entering each vertical layer of the modeling domain. UAM-V calculates the amount of radiation at each vertical layer based on surface reflectivity (albedo), atmospheric turbidity (haze), and the amount of stratospheric ozone that sunlight must pass through (the ozone column). Albedo is derived from the UAM-V Land Use file described above, and varies across the modeling domain based upon local characteristics of the land surface, but does not vary over time. Turbidity is set at .094, a value typical of rural conditions, and does not vary in space or time. The ozone column data are obtained from the National Space Science Data Center, which archives data from Nimbus 7 satellite-based Total Ozone Mapping Spectrometers (TOMS). Ozone column varies across the modeling domain, and also varies from day to day.

Job Control File

This file, as its name implies, contains information required to actually execute the modeling program, including the names of the various input data files.

(3) Base Case Model Execution

Once the required files have been developed and quality-assured, the model is executed and the output is examined to check for gross errors. Once the model is executing satisfactorily and the output files produced appear reasonable, then the model output is compared with ambient air quality measurements to evaluate its performance. If the model accurately replicates observed ozone concentrations, it is reasonable to believe the model can be reliably used to evaluate future control strategies (although the possibility that the model is "getting the right answer for the wrong reason" must always be considered). However, if the model cannot replicate observed ozone concentrations, then little confidence can be placed in its ability to correctly evaluate future control strategies.

It should be noted that in modeling the two episodes of primary interest for Houston/Galveston, the commission used two “ramp-up” days each (non-exceedance days preceding the actual exceedance days) to minimize any effects due to initial conditions. Model performance is discussed for the ramp-up days, but is not considered as important as model performance on the actual exceedance days.

(4) EPA Performance Evaluation Statistics

The EPA's *Guideline for Regulatory Application of the Urban Airshed Model* recommends three particular statistics for UAM performance evaluation. These statistics are the unpaired peak prediction accuracy, the normalized bias test, and the gross error. The formulae for calculation of these measures are provided in the *Guideline*.

Each of the recommended statistics provides useful information about the overall performance of the photochemical modeling. The unpaired peak prediction accuracy, which compares highest predicted 1-hour ozone concentration with the highest monitored 1-hour ozone concentration, irrespective of location or time, gives an overall indication of the ability of the model to replicate measured peak ozone levels. In particular, this statistic can be used to determine whether the model significantly underestimates the observed ozone levels. This statistic cannot be used to diagnose overprediction by the model, however. The true ozone peak on any day will likely exceed the monitored peak on that day, since only a few discrete locations within the domain are monitored. Thus when the model accurately predicts peak ozone, the peak modeled ozone concentration will exceed the peak measured value unless the peak happens to occur at a monitoring location.

The other two statistics match simulated and observed values paired in space and time, for data pairs where measured ozone concentrations are $\geq$ 60 ppb. The normalized bias test indicates whether or not there is a tendency of the model to overpredict or underpredict observed values. This statistic is the difference between simulated and observed ozone concentrations at each monitor for each hour, averaged over all hours and all stations where measured ozone is $\geq$ 60 ppb. Bias is negative if the model consistently underpredicts ozone, is positive if the model consistently overpredicts ozone, and is near zero if the model, on average, tends to predict the observed ozone levels. A value of bias which is near zero does not mean that the model is necessarily predicting the observed ozone concentrations correctly, however, only that the tendency to overpredict in some circumstances is balanced by a tendency towards underprediction in others.

The gross error measures the overall level of agreement between the model and monitored data, without regard to sign. This statistic is the absolute value of the difference between simulated and observed values, averaged over all hours and all stations where measured ozone is $\geq$ 60 ppb. The gross error is always positive; the smaller the gross error, the better the model replicates observations. However, unlike the bias, the gross error offers no information about whether the model has a consistent tendency to over- or underestimate observed ozone concentrations.

The *Guideline* also lists additional statistics that are useful in assessing model performance. The commission calculates these, as well as several others routinely when assessing model performance. The model performance summaries found in Appendix C include the complete set of statistics calculated for each model run.

The *Guideline* emphasizes the need for an adequate monitoring network from which to draw statistical inferences. The COAST study intensive monitoring, combined with the extensive state, city, and private monitoring networks in the region provide a very comprehensive data set upon which to base statistical calculations and thence to evaluate modeling performance. A map of COAST study monitoring sites used in the performance evaluation is given in Figure 7. The description of station codes and their associated geographical coordinates are attached to the statistical tables in Appendix C, *Performance Evaluation*. Note that two statistical calculation regions are shown in the figure. Performance as reported in this document is based on the western region (the Houston/Galveston area) only, although commission staff have also performed extensive model performance evaluations for the eastern (Beaumont/Port Arthur) region.

Figure 7

(5) Model Performance for COAST Episodes

As noted in the section of this document entitled “Model Episode Selection”, the commission selected two ozone episodes from the COAST study which were of particular significance to the Houston/Galveston nonattainment area. These episodes were August 16-20, 1993 and September 6-11, 1993. The following sections discuss model performance for these two episodes, and describe the choice of the episode ultimately selected for attainment demonstration modeling.

August 16-20, 1993

As noted in the “Model Episode Selection” section of this document, the August 16-20, 1993 episode had the highest monitored ozone concentration (231 ppb on August 19th) of any of the episodes under consideration. Furthermore, the 231 ppb ozone concentration recorded at Aldine in northern Harris County was greater than the Houston/Galveston design value of 220 ppb. Of the three exceedance days in this episode (August 18-20), two had wind flow patterns typically associated with high ozone in the Houston/Galveston area (August 18 and 20), while the third day (August 19) had a wind flow pattern similar (but not identical) to a wind flow pattern typically associated with high ozone (see Appendix A for detailed day-by-day descriptions of episode day meteorology). The episode also included days of widespread ozone exceedances; the ozone standard was exceeded at eight monitors in the Houston/Galveston area on both the 19th and 20th.

Performance Statistics

UAM-V model performance statistics for the August 16-20, 1993 episode are presented in Table 10 below. The analysis statistics include normalized bias and normalized gross error for ozone observations greater than 60 ppb and unpaired peak prediction accuracy. With each statistic is listed the EPA-recommended range denoting acceptable model performance. Statistics which fall within the acceptable range are highlighted in **bold** characters.

In general, the UAM-V did not replicate either the spatial or temporal ozone pattern for this episode, and failed to perform within EPA standards for model performance. Model performance appeared to be quite good on the two ramp-up days (August 16 and 17, 1993), with the exception of unpaired peak accuracy. As explained above, overprediction of the measured peak ozone concentration is not necessarily an indication of poor model performance, since the actual peak can occur in an area of the domain not covered by the monitoring network. Model performance also appeared to be good on the 18th, but this day had a recorded peak concentration of only 139 ppb, well below the Houston/Galveston nonattainment area's design value of 220 ppb. On the days of primary interest, namely the 19th and 20th, model performance was very poor, and clearly the model was generally underpredicting ozone concentrations by a significant amount.

Table 10. UAM Statistics for August 16-23, 1993

Episode Date	Normalized Bias (+/- 5-15%)	Gross Error (30-35 %)	Unpaired Peak Accuracy (+/-15-20%)	Simulated Peak Ozone	Measured Peak Ozone
8/16/93	**2.4**	**19.6**	39.3	145.	104.
8/17/93	**-0.1**	**30.7**	35.8	162.	119.
8/18/93	**3.9**	**23.9**	**16.7**	162.	139.
8/19/93	-30.8	36.3	-34.1	152.	231.
8/20/93	-35.6	37.3	-20.6	149.	187.

In an attempt to determine the cause of the poor model performance for this episode, a total of 83 modeling runs were prepared, executed and evaluated. About 25% of the 83 modeling runs were performed during the development and subsequent evolution of the base case, and the remaining 75% were performed as sensitivity runs, designed to help isolate the sources of the model's performance problems. Sensitivity runs were performed to examine the role of each of the various modeling components (meteorology, EI, boundary conditions, and model configuration) in the model's performance. A number of sensitivity runs were also conducted involving various combinations of these components, to determine if second-order interactions between the individual modeling components played a role in the model's poor performance. A summary table of these diagnostic and sensitivity runs is found in Appendix C.

Sensitivity analyses involving meteorological inputs focused primarily on adjusting the mixing among the first three model layers, adjusting the mixing height vertically, and extending daytime mixing later into the afternoon. The adjustments to vertical mixing near the ground were motivated by large discrepancies between measured and modeled precursor concentrations (NO, NO_2, and total VOC) at a number of sites. While several of these sensitivity analyses appeared to improve the model's performance relative to ozone precursors, none significantly affected domain peak ozone production or overall performance with respect to ozone. The usefulness of ozone precursor model performance will be discussed in greater detail later in this report.

Sensitivity analyses involving emissions inputs included many combinations of NO_x reductions and/or VOC increases applied to various components of the inventory. The directions of NO_x and VOC changes were chosen so that modeled VOC/NO_x ratios would be more consistent with monitored ratios, which tended to be much higher than their modeled counterparts. Overall, it was noted that modest changes to the inventory elicited little improvement in model performance, while very large changes could significantly improve model performance on the 19th and 20th, where the model had been underpredicting. Unfortunately, the large changes which improved model performance on the 19th and 20th also caused the model to significantly overpredict on first three episode days, which had formerly exhibited good performance.

Two of the early sensitivity analyses performed for this episode are particularly noteworthy, since the results of these analyses were used to guide further modeling for all the COAST episodes. In the first, meteorological inputs developed with a new version of the SAIMM meteorological model were tested. The revised meteorological model "nudges" modeled meteorological fields towards surface observational data during execution (the meteorological modeling performed for COAST episodes is documented in detail in Appendix A). The new version of SAIMM was used afterwards in all COAST modeling, primarily because it's predicted temperature data matched observed data much more closely than did its predecessor's. However, model performance of the August 16-20 episode was largely unaffected by the version of meteorological model used.

A second sensitivity analysis led to a change in the model formulation involving the definition of the fine-grid areas in the model. As described in Appendices A and B, the original modeling domain included two 2 km $\times$ 2 km subgrids which covered the central portions of the Houston/Galveston and Beaumont/Port Arthur nonattainment areas. Early sensitivity analyses comparing the model with and without the 2 km $\times$ 2 km subgrids indicated that the results differed little between the two model formulations. Because the 2 km $\times$ 2 km subgrids added significantly to the run time of the model, yet had little effect on the final results, the subgrids were not used in later modeling analyses.

Finally, as a result of continued performance problems, the August 16-20, 1993 episode was dropped from consideration for the attainment demonstration modeling.

Graphical Analysis

Commission staff produced a suite of graphical representations of modeled ozone and precursor concentrations for every base case development model run and for every sensitivity analysis performed for this episode. These analysis tools were used to help understand the model's poor performance for the August 16-20 episode and to guide subsequent sensitivity analyses. A discussion of the graphical analysis tools used by commission staff is given in the discussion of the September 6-11 episode below. Appendix C includes graphics depicting the final base case (September 6-11, 1993), and graphics for the additional model runs performed for this episode are kept in the commission SIP Modeling Unit's files (available upon request from the commission).

September 6-11, 1993

The September 6-11, 1993 ozone episode included four consecutive exceedance days beginning on September 8, and continuing through September 11, 1993. September 6 and 7 were modeled as ramp-up days. As noted in the "Modeling Episode Selection" section of this document, this episode included two days (8th and 11th) having wind patterns typically associated with high ozone in the Houston/Galveston area, while a third day (September 10th) had a wind flow pattern similar (but not identical) to a wind flow pattern typically associated with high ozone. The second highest ozone concentration measured during the COAST study (214 ppb on September 8th at Smith Point) was recorded during this episode. On three of the days, the highest ozone occurred in coastal areas, while on the fourth, the highest ozone occurred in the Houston area proper. This single episode provided an opportunity to model four consecutive days of ozone exceedances in the Houston/Galveston area.

Performance Statistics

The September 1993 episode clearly had acceptable statistical model performance, as shown in Table 11. Data for all three EPA statistics fell within the acceptable range on all of the days when the observed ozone exceeded the NAAQS. In fact, throughout the entire 6-day simulation period, only one statistic was outside the recommended range (overprediction), namely the unpaired peak accuracy on September 7, which was a ramp-up day. As discussed earlier, a positive value of this statistic may merely reflect the fact that it is not possible to monitor air quality at every point in the region, rather than indicating overprediction by the model.

Table 11. UAM Statistics for September 8-11, 1993

Episode Date	Normalized Bias (+/- 5-15%)	Gross Error (30-35 %)	Unpaired Peak Accuracy (+/-15-20%)	Simulated Peak Ozone	Measured Peak Ozone
9/6/93	**1.3**	**15.0**	**14.5**	156.	136.
9/7/93	**0.3**	**19.6**	39.4	155.	111.
9/8/93	**2.9**	**24.0**	**-13.1**	186.	214.
9/9/93	**4.3**	**26.1**	**-8.5**	179.	195.
9/10/93	**-10.0**	**22.7**	**10.7**	179.	162.
9/11/93	**-1.1**	**21.4**	**-1.29**	185.	189.

Although model performance was within acceptable limits, it is notable that the model was unable to reproduce the very high peak ozone recorded on September 8th of 214 ppb (although the model did predict a very significant ozone peak concentration of 186 ppb). The failure of the model to match the observed maximum at Smith Point (as well as at Seabrook across Galveston Bay, which recorded a maximum of 208 ppb) indicates that, while the model generally was able to reproduce the ozone cloud in time and space, it could not reproduce the conditions leading to the extreme values recorded in the Galveston Bay area. Commission staff are continuing to investigate the performance of the model for September 8th through a detailed analysis procedure known as process analysis, with the goal of eventually better characterizing the conditions leading to events like those that occurred on September 8, 1993 and on August 19, 1993.

Graphical Analysis

Statistical analysis is useful because it distills the comparison of modeled and observed concentrations for all time and space pairs into a few numbers which can be compared to accepted norms. However, the model output contains many megabytes of information for each episode day, and invariably much of the information contained in the raw output file is lost as the data are transformed into concise measures. Graphical analysis techniques allow the analyst to view a much larger set of model output at once, but unlike the performance statistics require some level of subjective interpretation in order that inferences be drawn about model performance.

The graphical analysis described in the next few paragraphs examine either temporal and spatial model dependencies using time series plots and isopleth plots, respectively. Time series plots illustrate model performance over time, but each plot is restricted to a single location in space (usually at a monitoring location). Isopleth plots (often called contour plots) show the spatial distribution of ozone and its precursors for a single time period (either one hour or daily summary), but cannot illustrate the variation of these pollutants over time. Commission staff have developed color video representations of surface pollutant concentrations which allow the model's output to be analyzed across space and time. Selected video representations of model output can be obtained from the commission upon request. Finally, the graphics described above are usually generated for surface concentrations only. Performance of the model in the vertical dimension is difficult to analyze due to a paucity of data, but vertical profile plots showing pollutant concentrations as they vary in the vertical can be useful to understanding the model's operation, and in limited instances can be used to compare model output to aircraft sampling data. Commission staff generated numerous vertical profile plots, and a sample of these are provided in Appendix C.

(6) Ozone Time Series

This section discusses time series plots for ozone and several other pollutants at four selected monitoring stations. Similar plots were developed for all the monitoring stations shown in Figure 7, and these are provided in Appendix C. The time series selected for discussion include the sites at Galveston (GALC as shown on the map in Figure 7), Smith Point (SPTC), Seabrook (SBRC) and Galleria (GLRC). These sites offer a cross section of monitors from the coast to the inner city of Houston. In comparing the modeled and monitored concentrations, three aspects will be noted: The first is whether the peak is over or under predicted, the second is whether the modeled values show a similar pattern of daily ozone growth and dissipation, and the third is whether there is a shift in time between the monitored and modeled concentrations.

As shown in Figure 8, at GALC (Galveston) the model somewhat overpredicted the monitored maximum on September 8 and slightly underpredicted the monitored maximum on September 10. Toward evening, the modeled ozone concentrations tended to lag behind the monitored values. However, the overall temporal pattern was well represented by the model throughout the episode.

A little further inland at SPTC (Smith Point) where the episode maximum ozone concentration was recorded on September 8, the model underpredicted the ozone maximum on each day of the episode (see Figure 9). The model did a good job of following the morning upward trend and evening downward trend of the monitored ozone values. With the exception of not hitting the peaks the model did a good job of following the general monitored pattern.

Further inland yet, at SBRC (Seabrook), the modeled concentrations again failed to reach the observed maximum ozone on September 8 and September 11 (see Figure 10). The modeled concentrations also tended to lag behind the monitored morning ozone increase and the evening dissipation of ozone, although the model did a fairly good job of representing the evening dissipation on September 8 and September 9.

Finally in the Houston metropolitan area, the model did a good job of predicting the ozone maximum on all days of the episode at the GLRC (Galleria) site (see Figure 11). The model also did a good job of following the daily monitored pattern on all days of the episode. Only on September 10 did the model lag behind the afternoon monitored dissipation of ozone.

Figure 8

Figure 9

Figure 10

Figure 11

In summary the model underpredicted the afternoon peak values at some of the monitoring site locations, but, in general, did a good job of following the overall pattern of the monitored ozone values.

The time series can also be used to evaluate precursor concentrations as an additional check on model performance. Nitric oxide (NO) concentrations appeared well represented at Seabrook and Galleria during this episode. Only two monitoring sites in the region had continuous hydrocarbon measurements, one of those being the Galleria, and for this episode the Galleria site had predicted concentrations of the correct order of magnitude, even though the measured variability was not reproduced well. The comparison of precursor concentrations can be important for diagnostic purposes when the modeled ozone seems to be poorly reproduced; in fact, for the August 1993 episode, precursor analysis prompted a careful review of NO_x/VOC ratios in the ambient data. However, the EPA's *Guideline for the Regulatory Application of the Urban Airshed Model* does acknowledge a well known caveat:

> Performance measures should also be considered for ozone precursors wherever possible, based upon availability of monitored data. Obvious problems exist in comparing model predictions with observed values. The UAM output represents volumetric (e.g., 25 km^3), 1-hour average concentrations, but air quality data represent point locations with various sampling periods. This “incommensurability” may lead to considerable uncertainty in the comparisons, especially for precursor species that are not buffered chemically and may have been sampled at locations not representative of area wide concentrations. (Page 50 of the *Guideline*).

Because of the above consideration, and because of additional technical concerns, the commission does not believe it is appropriate to base model evaluation on ozone precursor performance. The precursor comparisons are, however very valuable in lending insight into the model's operation.

(7) Maximum Ozone Concentration Isopleths

Although commission staff have produced and evaluated a very large number of 1-hour ozone isopleth plots, these are not shown here but can be obtained from the commission upon request. The isopleth plots presented below represent daily maximum ozone concentrations over the domain, and do not represent the ozone distribution at any particular time. These isopleth plots summarize daily high ozone better than any single 1-hour plot, so are considered more useful for comparing the effectiveness of various emission reduction strategies. Figure 12 shows daily maximum predicted ozone for the September 8, 1993 base case (note that this figure was generated for the 4 km $\times$ 4 km fine grid area only, not the entire COAST domain. As indicated in the figures, the darker shaded grid cells are those for which ozone concentrations were predicted to be greater than 124 ppb (i.e. above the 1-hour ozone standard). Maximum ozone isopleth plots for the remaining episode days are given in Appendix C.

Figure 12

In the following section, results from a series of diagnostic and sensitivity model runs are presented. Daily maximum ozone isopleths for one day (September 8) of each diagnostic/sensitivity run are provided, along with another useful type of isopleth plot called a difference plot. Difference plots show the difference, at each location in the modeling domain, between daily maximum ozone simulated for a particular diagnostic or sensitivity and the daily maximum at that location simulated by the base case. These plots are useful because they show the geographic regions where peak ozone increased and where it decreased, compared with the base case.

Diagnostic Runs

The goal of diagnostic testing is to determine whether the model exhibits expected behavior under extreme changes to its input. Diagnostic tests check for spurious behavior that would indicate problems in the model formulation . Of course diagnostic tests alone do not constitute a complete validation of the UAM for a given episode, but rather provide opportunities for the model to fail.

- **Zero Anthropogenic Emissions** - The first diagnostic test involved setting all anthropogenic emissions in the COAST domain to zero. This modeling is expected to produce very low ozone concentrations across the modeling domain, except in cases where the boundary conditions contribute significantly to the modeled ozone values. Figure 13 shows daily maximum ozone concentrations simulated with no anthropogenic emissions in the COAST domain, and Figure 14 shows the difference between the zero anthropogenic emissions case and the base case. One feature which is immediately obvious in Figure 13 is the large cloud of high ozone over the Gulf of Mexico south of the Beaumont/Port Arthur area which, entered the domain from southern portion of the eastern boundary. Because no monitoring data are available over the Gulf on September 8, 1993 to verify the levels of ozone and precursor concentrations, the existence of this ozone cloud (or at least its magnitude) is somewhat of an open question. In a sensitivity analysis discussed below which used boundary conditions developed based on modeling performed during the GMAQS, daily peak ozone concentrations in the same area were only in the 65-85 ppb range.

Of the four exceedance days in this episode, September 8th was the only one showing substantial levels of ozone transported into the domain from the boundaries. However, both ramp-up days (September 6th and 7th) showed significant levels of ozone transported into the domain from the southeastern boundary region, similar to what was seen on the 8th. Isopleth and difference plots for the four exceedance days are provided in Appendix C.

Figure 13

Figure 14

- **Zero Boundary and Initial Conditions** - The second diagnostic test conducted consisted of setting all boundary conditions, initial conditions, and region-top conditions to have zero concentrations of all chemicals. Maximum ozone isopleth and difference plots for September 8th are shown in Figures 15 and 16, respectively. Because September 8th is the third day modeled, the effects of initial conditions have largely been dissipated by this time. Consequently, the figures for the 8th illustrate primarily the contribution of the boundary conditions to total ozone levels in the region. Figure 15 shows that without the contribution of boundary conditions, the model was capable of only producing ozone concentrations in the 113 ppb range, and Figure 16 shows the difference between this case and the base case. As might be expected from the discussion of the previous diagnostic run, the largest difference occurred over the Gulf in the area of the transported ozone cloud discussed above.

  Overall, the results of this diagnostic were consistent with expectation. Maximum ozone isopleth and difference plots for the four exceedance days in this episode are provided in Appendix C.

Figure 15

Figure 16

(8) Sensitivity Runs

The classic function of sensitivity analysis applied to models of complex physical systems is to assess the stability of the models across a range of possible input parameters. In other words, the model should respond to small changes in critical input parameters, but not in an extreme or erratic fashion. Detection of either a lack of responsiveness or of a tendency to respond excessively to realistic perturbations in the model's input can indicate possible problems with the selection of a particular episode.

The primary role of sensitivity analysis when model performance is poor is to provide vital information to the modeler for model evaluation. In this application, the results of sensitivity analysis are used to identify those input data that have a significant effect on model results. Consequently, in an attempt to improve model performance, the modeler would investigate those areas first for possible error. Since the overall performance for the September episode is good, these sensitivity analyses are viewed as additional checks on model behavior and provide reasonable bounds on model output.

- **GMAQS Boundary Conditions** - also called the MMS boundary conditions (since the Minerals Management Service, or MMS, was the client for whom the GMAQS was conducted). Because the GMAQS modeling domain covered the southern and eastern boundaries of the COAST domain, many of the earlier COAST model runs were conducted using boundary conditions derived from GMAQS model output. After the regional modeling results became available, the commission switched to using boundary conditions based on its own regional modeling study. The primary advantages of the regional modeling-derived boundary conditions versus the GMAQS-derived boundary conditions are that the commission's regional modeling domain encompassed the entire COAST domain (unlike the GMAQS domain, which only extended to the south and east of the COAST domain), and the commission regional modeling used a more current regional EI which was based on the OTAG inventory.

Maximum ozone isopleth and difference plots for September 8th are shown in Figures 17 and 18, respectively. These figures indicate that ozone concentrations across the region are generally higher with the commission regional model-based boundary conditions than with the GMAQS-based boundary conditions. Figures for the episode’s four exceedance days, provided in Appendix C, show a similar pattern. Also provided in Appendix C are model performance statistics for this and the remaining sensitivity analyses discussed below. Comparing these statistics to those of the base case model indicate overall better performance using the commission regional model-based boundary conditions than was obtained with the GMAQS-derived boundary conditions.

Figure 17

Figure 18

- **One Half Wind Speed** - This sensitivity analysis was performed to assess the model's response to changes in the wind speeds used in the model. The expected result of this sensitivity is a general increase in modeled ozone over the base case, since lower wind speeds cause ozone and its precursors to disperse more slowly. In this model execution, the wind fields input to UAM-V were reduced by half at all locations and for all hours prior to running the model.

  Maximum ozone isopleth and difference plots for September 8th are shown in Figures 19 and 20, respectively. These plots indicate that, as expected, ozone levels were increased over most of the modeling domain. Peak ozone reached a maximum of 216 ppb on the 8th, although peak modeled ozone concentrations at Smith Point and Seabrook were still significantly below their monitored values. Plots and performance statistics for each exceedance day of episode are provided in Appendix C.

Figure 19

Figure 20

- **Alternate EI I** - This sensitivity was designed to test model performance assuming an EI that was adjusted to agree more closely with ambient data. Because ambient data analysis indicated that modeled VOC/NO_x ratios are likely too low, this alternative inventory (as well as a second alternative inventory discussed below) was developed to increase emissions of anthropogenic VOC and reduce emissions of anthropogenic NO_x, as compared to the base case inventory. A team of commission staff members each possessing extensive knowledge of one or more components of the inventory was convened to estimate the largest adjustments which could be reasonably made to the various inventory components, in the direction of increasing NO_x and decreasing VOC emissions. One additional change the team felt was warranted involved reducing biogenic VOC emissions, since ambient data analysis in two urban locations indicated that biogenic VOC emissions may be overestimated significantly, at least in urban districts. Table 12 shows the specific inventory adjustments that were applied to the base case inventory to create Alternative Inventory I.

Table 12. Alternative Inventory I

EI Source Category	Adjustment Factor	
	VOC	NO_x
Point	1.25	0.75
On-Road Mobile	2.00	0.80
Area/Non-Road Mobile	1.30	0.25
Biogenic	0.30	1.00

The increased VOC/NO_x ratio for the anthropogenic sources would be expected to increase overall ozone levels; however the decreased biogenic VOC emissions would be expected to reduce ozone. As seen in Figures 21 and 22, ozone levels over land were generally lower, but a large plume of ozone extending into the Gulf from Galveston Bay was seen to have significantly elevated ozone levels. For this emissions scenario, plots and performance statistics for each exceedance day of this episode are provided in Appendix C. It is worth noting that with Alternative Inventory I, model performance was generally acceptable, based on performance statistics, except that on the 10th the Normalized Bias was outside the recommended range (too low), indicating general underprediction. Compared to the base case, Alternative I is more negatively biased overall, but on all days the relative error is slightly lower than with the base case.

Figure 21

Figure 22

Alternate EI II

This sensitivity was conducted with a second alternative inventory differing from the first only in the treatment of biogenic VOC emissions. The staff committee concluded that enough uncertainty in biogenic emissions existed to warrant consideration of a second alternative inventory. In Alternative Inventory II, urban biogenic VOC was adjusted by a factor of .6 (40% reduction), while non-urban biogenic emissions were left unchanged from the base inventory. This inventory assumes that biogenic emissions in rural areas are accurately characterized, while those in urban areas are over-represented in the inventory. As with Alternative I, the increased VOC/NO_x ratio for the anthropogenic sources would be expected to increase overall ozone levels and the decreased biogenic VOC emissions would be expected to reduce ozone, but not so much as in Alternative I, where the biogenic VOC reductions were much larger.

Figures 23 and 24 show that overall maximum ozone levels are fairly similar to those of the base case, except that ozone levels in southern Harris county and in the Gulf near the entrance to Galveston Bay are significantly increased, with some minor ozone reductions in rural areas. Plots and performance statistics for each exceedance day of this episode are provided in Appendix C. Performance statistics for this sensitivity analysis show acceptable performance on each day, with overall performance similar to that seen in the base case.

Figure 23

Figure 24

(9) Comparison between UAM-V and UAM-IV

The regulatory version of the UAM is UAM-IV (version 620). However, the variable-grid version of the UAM, called UAM-V, incorporates many important technical enhancements. In January 1995, commission staff and representatives from the Technical Oversight Committee met with EPA Region 6 and EPA Headquarters, and obtained approval to use UAM-V provided the commission conduct and present a comparison of the performance of UAM-IV with UAM-V. The technical features of the UAM-V which motivated its use were described under “Model Selection” earlier in this report. In this section, the performance of the two UAM versions is compared for the September 1993 episode, and UAM-V is seen to outperform its predecessor.

Commission staff conducted base case modeling for the September 1993 episode using UAM-IV and UAM-V version 1.24 (UAM-V with the improved isoprene chemistry developed for OTAG). The UAM-IV modeling domain was considerably smaller than the UAM-V domain, and in fact coincided exactly with the 4 km × 4 km nested grid of the UAM-V domain. Except for a slightly larger domain and use of 4 km × 4 km grid cells (rather than 5 km × 5 km), the UAM IV model set up was similar to that used in the previous modeling for the region (Houston/Galveston Base Case Report, TNRCC, 1994). The wind fields and mixing heights used for the UAM-IV modeling were extracted from the SAIMM wind fields developed for UAM-V. Mixing height data for UAM-IV was also derived from SAIMM vertical diffusivity output, but was subsequently modified so that the overnight minimum mixing heights were specified by radar profiler data, rather than SAIMM. Emissions data for UAM-IV was extracted from the COAST gridded emissions and placed into a 4 km × 4 km grid. Boundary conditions for the UAM-IV domain were extracted from the regional modeling output in the same manner as was performed for the UAM-V domain, but this time were extracted specifically for the smaller UAM-IV domain.

Complete tabulations of statistics for both UAM-V and UAM-IV are included in Appendix C. A summary of the recommended EPA statistics presented in Table 13 below shows better performance by UAM-V version 1.24 than by UAM-IV. The table also includes peak predicted ozone for the two models by day.

Table 13. Comparison of UAM-IV and UAM-V Bias, Gross Error, and Accuracy

Episode Date	Maximum Predicted Ozone Conc. (ppb)		Normalized Bias (5-15%)		Gross Error (30-35%)		Unpaired Peak Accuracy (+/-15-20%)	
	UAM-IV	UAM-V	UAM-IV	UAM-V	UAM-IV	UAM-V	UAM-IV	UAM-V
9/8/93	178	186	-11	2.9	29	24	-16.6	-13.1
9/9/93	193	179	3.4	4.3	32.8	26.1	-1.0	-8.5
9/10/93	209	179	-10	-10	29.5	22.7	28.9	10.7
9/11/93	171	185	-10	-1	25.8	21.4	-9.4	-1.9

Overall, UAM-IV showed considerably more variability in daily peak ozone levels than did UAM-V. The UAM-IV generated a higher overall peak concentration (209 ppb) than did UAM-V (186 ppb), but UAM-IV simulated its highest peak on September 10th, the day which had the lowest observed peak concentration (162 ppb). On September 8th, the day the episode maximum observed ozone concentration of 214 ppb was recorded, UAM-IV only generated a peak of 178 ppb. In fact, the Unpaired Peak Accuracy with UAM-IV was better than that of UAM-V only on one day, September

9th. Looking at Normalized Bias, UAM-IV was slightly better than UAM-V on the 9th, tied with UAM-V on the 10th, and performed worse on the remaining two episode days. UAM-V outperformed UAM-IV in Gross Error on all four days. Figure 25 presents a plot of normalized gross error versus the normalized bias for each day of the September 1993 episode. This figure graphically represents the comparative performance of the two models for the four exceedance days of the September 6-11 episode.

Because of its superior statistical performance, and because UAM-V incorporates many technological improvements over UAM-IV including improved isoprene chemistry, UAM-V is clearly the superior model for this episode.

Figure 25

(10) Conclusions

Despite a great deal of effort on the part of commission staff, model performance for the August 18-20, 1993, episode could not be made acceptable. The episode was dropped from consideration in the modeling attainment demonstration. Overall model performance for the September 8-11 episode appears to be very good, including performance on the two ramp-up days. The fact that the model exhibits consistently good performance across a number of days, encompassing several meteorological regimes, gives confidence that the model can be reliably used in control strategy development. Nonetheless, the inability of the model to reproduce the extremely high measured ozone concentrations recorded on September 8th indicate that some aspects of the ozone episode are not simulated accurately.

The model responded as expected to sensitivity and diagnostic analyses, except that on September 8th one diagnostic highlighted a large influence from the eastern boundary which is unconfirmed. Sensitivity analyses indicate that model performance would still be generally acceptable using either of two alternative emissions inventories designed to more closely replicate ambient VOC/NO_x ratios. For the September 8-11 episode, model performance using UAM-V version 1.24 is superior to the performance of UAM-IV, and therefore the UAM-V, version 1.24 will be used for this attainment demonstration.

Finally, the commission recognizes that there are many factors involved in the formation of ozone along the Texas coast, and that much remains to be learned. The commission will continue to collect and analyze monitoring and EI data and develop improved characterizations of the meteorology and emissions in the region, and will continue to improve its modeling approaches. The attainment demonstration for the new 8-hour standard, due in 2003, will provide an opportunity for the commission to apply the knowledge obtained from the COAST project to future modeling efforts.

n) Future Year (2007) EI

As noted previously, the goal of this modeling study was to determine the level of reductions of ozone precursors necessary for demonstrating attainment of the 1-hour ozone NAAQS in the Houston/Galveston nonattainment area by the federally mandated attainment year of 2007. In order to accurately assess the ozone concentrations for the area when emissions are at the predicted 2007 levels, the commission developed an EI that best represents the level of emissions expected in the year 2007 for the entire modeling domain, which includes not only the Houston/Galveston nonattainment area but also the Beaumont/Port Arthur nonattainment area. This inventory can be referred to as the "base" future year inventory; that is, the inventory projected to 2007 which reflects controls already in place or required by existing rules or regulations to be put in place. The base 2007 inventory does not include additional controls which may be required for bringing the Houston/Galveston area into attainment. Additionally, the base 2007 inventory does not include certain on-road mobile source controls which were implemented after development of the 2007 mobile source inventory (this will be discussed in more detail later in this document).

The following section discusses the development of growth factors used to predict the year 2007 emission levels, based on the 1993 base year emission levels in the modeling domain. The subsequent subsections describe the growth, controls, and other enhancements that were applied to each source type. As in the 1993 base case inventory, the future year (or "projected") modeling inventory is composed of point source, on-road mobile source, area (including non-road mobile) source, and biogenic emissions. Later sections of this document will discuss modifications made to the base future year inventory in order to determine the reduction targets for ozone precursors necessary to demonstrate attainment of the ozone NAAQS.

Through the performance evaluation process, discussed in previous sections of this document, the commission (with input from other groups) concluded that the September 8-11, 1993 episode was the most appropriate episode at this time to use for further modeling of the COAST domain. As indicated in previous sections, the modeling was actually performed for September 6-11, 1993 to account for "ramp-up" days (to minimize the influence of initial conditions). Future year modeling was performed for the same days, so emissions for each day of this 6-day period were projected to the attainment year of 2007.

Although carbon monoxide is not of primary interest in ozone formation, it is accounted for in the Urban Airshed Model (UAM). Carbon monoxide will not be addressed in this chapter, but is included in summary tables located in Appendix D *Future Case Emissions Inventory*.

(1) Emissions Growth Factor Development

Future emissions inventories are "grown" from current inventories using factors based on projections for future industrial activity and population growth. Regional Economic Modeling, Inc. (REMI) developed a series of regional economic models which it uses to prepare a wide range of economic projections for clients. Economic Growth Analysis System (EGAS), a public domain model available through the EPA website, is an emissions growth factor development tool produced for the EPA to help states reasonably predict emissions growth for SIP purposes. The commission utilized a hybrid of these two tools to prepare the most accurate and timely growth factors available. However, the commission recognizes the inherent uncertainty involved in predicting emissions growth into the future.

The commission procured a 31-region economic model of Texas from REMI. The sixteen nonattainment area counties and five near-nonattainment counties in the state of Texas were treated as unique economic regions in the economic model, while each of the remaining counties in the state was assigned to one of ten regions based on the Texas State Comptroller's Economic Regional Boundaries map. Within each economic region, the REMI model categorized industry into 53 separate groups (according to 2-digit SIC groups). It also used the US Bureau of Labor Statistics national economic forecast for 1992-2005 (trended by natural labor force), and it used an updated short-term forecast from the University of Michigan's Research Seminar in Quantitative Economics (RSQE). The RSQE forecast used as model input had a release date of November 16, 1995.

The REMI model was executed for the period 1991 through 2015. The modeled results, which consisted of economic forecasts specific to each of the 53 economic sectors for each of the 31 Texas regions, were then used as input files to the growth factor module of EGAS, version 3.0. This module took the categorized economic forecast data from REMI and converted them into emissions growth factors classified by Area Mobile Source (AMS) code or Source Classification Code (SCC), which are the codes the emissions processor EPS-2 uses to identify sources by type. The growth factors were then written to one of seven ASCII output file types, based on source type.

Finally, the factors used to project emissions from 1993 to 2007 were calculated by simply extracting the 1993 and 2007 growth factors for each region/source category applicable to the COAST modeling domain, then dividing each 2007 factor by the corresponding 1993 factor. The resulting factors (the

1993 to 2007 growth factors) were, in turn, converted to a format suitable for input to EPS-2 using SAS programs developed by commission staff.

The traditional method of developing these growth factors would be through the use of EGAS alone, yet the commission took that method several steps further in an effort to obtain more accurate factors. The commission used the additional REMI economic data and most current forecast data (from RSQE) to gain a high degree of local and industrial differentiation, to improve on the EGAS regional defaults. This combined approach is hereafter referred to as REMI-EGAS.

Although the commission has used the best information available at the time to develop these factors, a significant amount of uncertainty exists whenever growth is projected into the future by 10-15 years. Emissions growth uncertainty is one reason that EPA allows states to use an alternative approach when using modeled results to demonstrate attainment. The following subsections discuss the application of growth and controls to the various source categories.

(2) Emissions Growth and Controls by Source Type

Point Sources

First, the point source emissions from the 1993 base case were “grown” using the REMI-EGAS model described above; second, quality assurance checks were employed; and third, any controls not in place in September, 1993, but required prior to 2007, were applied to the sources. A summary of the total emissions to the UAM, after these three steps were applied, is provided in summary tables later in this section.

Growth of Point Source Emissions

Table 14 summarizes emissions before and after growth factors were applied. Data for the September 8, 1993 episode day are shown as an example. Each nonattainment county (including those in the Beaumont/Port Arthur nonattainment area) is listed separately, as well as emissions for several regions. No growth was assumed for offshore point sources, which is consistent with the assumptions of OTAG. Because REMI-EGAS growth factors were not developed for Louisiana, growth for the Louisiana parishes was assumed to be the same as Jefferson County, which borders on Louisiana.

Table 14. Point Source Emissions by Region within the COAST Domain

Before and After Growth was Applied

Region	Sept. 8, 1993 (tons/day)		Projected 2007 (tons/day)	
	NO_x	VOC	NO_x	VOC
Brazoria Co.	107	56	111	63
Chambers Co.	56	17	62	19
Fort Bend Co.	87	4	98	4
Galveston Co.	108	69	116	78
Harris Co.	305	253	308	289
Liberty Co.	4	4	5	5
Montgomery Co.	21	4	23	4
Waller Co.	6	3	7	3
HGA NAA	**695**	**411**	**730**	**464**
Hardin Co.	6	8	6	8
Jefferson Co.	103	142	102	164
Orange Co.	66	29	74	34
BPA NAA	**175**	**179**	**182**	**206**
HGA/BPA NAAs	**870**	**590**	**912**	**670**
TX counties	1330	713	1400	812
LA parishes	152	59	153	63
TX+LA	**1481**	**771**	**1552**	**875**
Offshore	68	12	68	12
COAST Domain	**1549**	**783**	**1621**	**887**

Notes: NAA -- nonattainment area

HGA -- Houston/Galveston

BPA -- Beaumont/Port Arthur

Because the set of growth factors used to grow emissions to 2007 is quite lengthy, it is not provided in this report. Growth factors can be obtained from the commission upon request.

Controls Applied to Point Source Emissions

After point source emissions had been grown to 2007 levels, the next step was to apply any adopted controls which would become effective before 2007. Controls that took effect prior to September 1993, were assumed to have been in effect during the base case episode, so were specifically excluded from the list of controls applied. Any adopted controls scheduled to take effect after September 1999 were applied to this point source inventory. At the time the future base case inventory was developed (spring 1997), no controls on point source NO_x had been adopted. Both the Houston/Galveston and Beaumont/Port Arthur nonattainment areas were under temporary exemptions from the 1990 FCAA Amendments NO_x RACT requirements at the time. Although these exemptions have subsequently expired, time constraints prevented commission staff from explicitly incorporating the effect of NO_x RACT into the projected 2007 inventory.

A number of VOC controls were scheduled to take effect between September 1993 and 1999 (no point source controls beyond 1999 have as yet been adopted). These consist of the post-September 1993 portion of the original 15% ROP VOC reductions, which apply to both the Houston/Galveston and Beaumont/Port Arthur nonattainment areas, and the additional 9% ROP VOC reductions adopted for the Houston/Galveston nonattainment area. It should be noted that subsequent to development of the base 2007 inventory, EPA has proposed disapproval of part of the 9% ROP reductions; however, no attempt has been made in the modeling to account for loss of credit due to the proposed disapproval.

The VOC controls modeled fall into three broad classifications:

- Fix-ups -- controls which are already on the books, but cannot be counted toward the 15% ROP SIP.

- Catch-ups -- controls which are already on the books, but can be counted toward the 15% ROP SIP.

- New controls -- controls that are on the books, but have not taken effect yet.

These future controls were applied to the projected 2007 point source VOC EI subsequent to the application of growth factors. These controls apply only to the Houston/Galveston and Beaumont/Port Arthur nonattainment areas, since no rules have been adopted affecting point sources in the remainder of the COAST domain.

The commission's Air Policy and Regulations Division provided a list of controls which apply to Synthetic Organic Chemical Manufacturing Industry (SOCMI) reactors, separators, vacuum systems, vent gas, and polymer production; gasoline truck and marine terminal loading; fixed and floating roof tanks; marine vessel cleaning; cleaning and coating of metal cans, coils, automobiles, and appliances; wood pulp and paper mills; graphic arts; and industrial wastewater treatment. The control list also includes reductions of benzene emissions mandated by the National Emission Standards for Hazardous Air Pollutants (NESHAPS) rule. A complete list of all control factors by county and region, is given in Appendix D.

Table 15 below summarizes the results of applying VOC controls to the 2007 projected EI in each nonattainment county. Offshore sources of emissions were not controlled, nor were controls applied to Louisiana sources. As stated previously, no NO_x controls were applied, but NO_x has been included in Table 15 for completeness. As Table 15 demonstrates, the total 220.47 tons/day VOC reduction is due entirely to the controls applied to the Houston/Galveston and Beaumont/Port Arthur nonattainment areas. At this point, the emissions were ready for input to the UAM.

Table 15. Point Source Emissions by Region within the COAST Domain

Before and After Controls were Applied

Region	Projected 2007 (tons/day)			
	Before Controls		After Controls	
	NO_x	VOC	NO_x	VOC
Brazoria Co.	111	63	111	46
Chambers Co.	62	19	62	9
Fort Bend Co.	98	4	98	4
Galveston Co.	116	78	116	52
Harris Co.	308	289	308	188
Liberty Co.	5	5	5	3
Montgomery Co.	23	4	23	3
Waller Co.	7	3	7	1
HGA NAA	**730**	**464**	**730**	**305**
Hardin Co.	6	8	6	7
Jefferson Co.	102	164	102	112
Orange Co.	74	34	74	25
BPA NAA	**182**	**206**	**182**	**144**
HGA/BPA NAAs	**912**	**670**	**912**	**449**
TX counties	1400	812	1400	591
LA parishes	153	63	153	63
TX+LA	**1552**	**875**	**1552**	**654**
Offshore	68	12	68	12
COAST Domain	**1621**	**887**	**1551**	**654**

Notes: NAA -- nonattainment area

HGA -- Houston/Galveston

BPA -- Beaumont/Port Arthur

On-Road Mobile Sources

The on-road mobile source emissions estimates developed for the 1993 COAST project were designed to provide the most accurate, detailed modeling input possible using available tools. Development of projected 2007 COAST emissions, discussed in the following subsection, generally follows the same methodology as that used in developing the 1993 COAST emissions, except that some minor errors were corrected and the processing was greatly streamlined.

Growth of On-Road Mobile Sources

Emissions modeling for the 8-county Houston/Galveston and 3-county Beaumont/Port Arthur nonattainment areas was based on the results of travel demand models, and on hourly local temperatures and traffic characterization data collected in a special study conducted during the summer of 1993. As was the case with the 1993 COAST EI, 2007 projected mobile source emissions were produced by the Texas Transportation Institute (TTI) using a travel demand model (using a 2007 projected roadway network) and MOBILE5a. Methods used to project travel demand and network parameters are discussed in two TTI reports: 1) *Development of Gridded Mobile Source Emission Estimates for the Houston/Galveston Nonattainment Counties FY93, FY96, FY99 and FY07 in Support of the COAST Project, September 1995,* and 2) *Development of Gridded Mobile Source Emission Estimates for Jefferson, Orange, and Hardin Counties FY93, FY96, FY99, and 2007 in Support of the COAST Project, May 1997.* Dr. George Dresser, with TTI's Transportation Planning Program, was the principal investigator. Due to the extensive length of these two TTI reports, they have not been included with this report. Copies of these reports are available upon request from the commission.

Because TTI produced 2007 emissions estimates for only the August 17-21, 1993 episode, commission staff developed adjustment factors to produce emissions for September 6-11, 1993 based on temperature and seasonal activity differences. Additionally, the commission applied an adjustment to account for the differences between the travel demand model-generated VMT and Highway Performance Monitoring System (HPMS) VMT. The process followed is similar to that used to develop emissions for the September episode in the base case, described in detail in Appendix B, Chapter 3, *On-road Mobile Source Emissions*.

A detailed summary table of future year mobile emissions for the Houston/Galveston and Beaumont/Port Arthur nonattainment areas is provided in Table 16. The table lists the nonattainment area total emissions originally provided for the August 1993 episode by TTI and emissions for the September 1993 episode on a day-by-day basis. For example, the 2007 emissions provided for August 17 by TTI were adjusted for temperature and seasonal VMT differences to produce emissions for September 7. As in the base case modeling, the emissions developed for September 7 were used for September 6 as well (since the actual ozone episode does not begin until September 8, developing precise emissions estimates for September 6 was considered unnecessary).

Projected 2007 emissions for the attainment counties were developed by applying regional adjustment factors to the August 1993 attainment county emissions inventories. These factors were based on: 1) differences in 1993 and 2007 emission factors, as calculated by MOBILE5a, and 2) differences in 1993 and 2007 vehicle miles traveled (VMT), from HPMS estimates provided by the Texas Department of Transportation (TxDOT).

Controls for On-Road Mobile Sources

At the time the on-road mobile source emissions were developed by TTI, the future Inspection/Maintenance (I/M) program for the Houston/Galveston nonattainment area had not been finalized. This uncertainty in the scope of the final program led the commission and TTI to agree that the 2007 emissions would be modeled with the same MOBILE5a parameters as were used in the 1993 base case, except for changing the evaluation year from 1993 to 2007. Thus any reductions in emissions from 1993 to 2007 in the emissions estimates from TTI will be due to the introduction of cleaner vehicles under the Federal Motor Vehicle Control Program (FMVCP) and to the retirement of older, more polluting vehicles.

Subsequent to the development of the 1993 base inventory, Texas has adopted a Motorist's Choice I/M program in Harris County, which will reduce emissions of VOC below the previously estimated 2007 levels. Additional elements not included in the 2007 inventory are the introduction in 1995 of reformulated gasoline (RFG) phase 1 (1995) and the scheduled introduction of RFG phase 2 in 2000 for the 8-county Houston/Galveston ozone nonattainment area. Taken together, these elements are expected to provide approximately a 35% reduction in the 2007 on-road mobile source VOC emissions, or approximately 75 tons/day of VOC (assuming full centralized I/M emissions credit for the Motorist's Choice program). These reductions amount to about 9% of the total 2007 projected anthropogenic VOC emissions inventory. The Motorist's Choice and RFG programs are also expected to provide a small reduction in NO_x emissions as well (about 17 tons/day, which is just over 1% of the 2007 projected anthropogenic NO_x inventory).

Before using the UAM to develop and test *specific* control strategies (a future application beyond the scope of the current SIP), commission staff will adjust the 2007 mobile source emissions to account for the Motorist's Choice I/M program and RFG. Table 16 below summarizes the on-road mobile source emissions after growth and controls have been applied. Because of the methodologies used to develop future mobile source emissions, it was not possible to report growth separately from controls for these sources.

Table 16. On-Road Mobile Emissions Summary within the COAST Domain

Region	Sept. 8, 1993 (tons/day)		Projected 2007 (tons/day)	
	NO_x	VOC	NO_x	VOC
Brazoria Co.	19	8	38	15
Chambers Co.	9	3	6	2
Fort Bend Co.	23	11	22	10
Galveston Co.	17	9	17	8
Harris Co.	310	153	343	160
Liberty Co.	7	3	6	3
Montgomery Co.	25	10	23	10
Waller Co.	5	2	6	2
HGA NAA	**416**	**199**	**462**	**210**
Hardin Co.	5	2	4	2
Jefferson Co.	28	14	22	12
Orange Co.	12	6	9	4
BPA NAA	**51**	**25**	**35**	**18**
HGA/BPA NAAs	**467**	**223**	**497**	**228**
Attainment counties/parishes	301	187	179	147
COAST Domain	**768**	**410**	**676**	**375**

Notes: NAA -- nonattainment area

HGA -- Houston/Galveston

BPA -- Beaumont/Port Arthur

Area and Non-road Mobile Sources

Growth of Area and Non-road Mobile Emissions

The area (including non-road mobile) source emissions were grown using REMI-EGAS, in the same way as the point sources, previously described. The area source emissions, before and after growth was applied, are summarized in Table 17.

Table 17. Area Source Emissions by Region within the COAST Domain

Before and After Growth was Applied

Region	Sept. 8, 1993 (tons/day)		Projected 2007 (tons/day)	
	NO_x	VOC	NO_x	VOC
Brazoria Co.	16	22	19	26
Chambers Co.	14	13	18	17
Fort Bend Co.	8	16	9	19
Galveston Co.	26	26	33	30
Harris Co.	149	202	181	244
Liberty Co.	5	10	5	12
Montgomery Co.	7	22	8	25
Waller Co.	2	4	2	5
HGA NAA	**226**	**318**	**276**	**378**
Hardin Co.	2	6	3	7
Jefferson Co.	24	29	30	33
Orange Co.	7	8	8	10
BPA NAA	**33**	**44**	**42**	**51**
HGA/BPA NAAs	**259**	**362**	**317**	**428**
TX counties	347	819	422	969
LA parishes	41	48	52	55
TX+LA	**388**	**867**	**474**	**1024**
Offshore	136	17	136	17
COAST Domain	**501**	**767**	**445**	**1041**

Notes: NAA -- nonattainment area

HGA -- Houston/Galveston

BPA -- Beaumont/Port Arthur

Controls Applied to Area and Non-road Mobile Emissions

Various VOC controls were applied to area (including non-road mobile) source emissions. No NO_x or CO controls were applied, since no controls were included in existing regulations that were to take effect prior to 2007. Table 18 lists the area and non-road mobile source VOC controls, their applicable counties/regions, and corresponding VOC control factors.

Table 18. Area Source Control Factors by County/Region and ASC

Control Description	ASC	Applicable Counties/Regions	VOC Control Factor
TSDFs	2640000000	COAST Domain	0.0700
Stage II Refueling 9%	2501060100	HGA and BPA NAAs	0.1621
Auto Refinishing	2401005000	HGA NAA	0.6000
Architectural Coatings 9%	2401001000	COAST Domain	0.8000
Coating: Traffic Markings 9%	2401008000	COAST Domain	0.8000
Coating: Industrial Maintenance 9%	2401100000	COAST Domain	0.8000
Coating: Other Special 9%	2401200000	COAST Domain	0.8000
Coating: Consumer/Commercial Products	2465000000	COAST Domain	0.8000
Coating: Wood Furniture	2401020000	HGA NAA	0.8725
Coating: Metal Cans - RE Improvement	2401040000	Harris	0.9794
Cutback Asphalt - RE Improvement	2461021000	Brazoria, Galveston, Harris, Jefferson, Orange	0.9254
Tank Truck Unloading 9%	2501060050	Brazoria, Galveston, Harris	0.5827
Tank Truck Unloading - Catch-ups 9%	2501060050	Chambers, Fort Bend, Hardin, Jefferson, Liberty, Montgomery, Orange, Waller	0.1357
Surface Cleaning - RE Improvement	2415300000	Harris	0.9544
Coating: Mach.&Equipment - RE Imp.	2401055000	Harris	0.9706
RE Improvements	2401015000	Harris	0.9686
Tank Trucks in Transit - Catch-ups	2505030120	Chambers, Fort Bend, Hardin, Liberty, Montgomery, Waller	0.1925
Tank Trucks in Transit - RE Improvements	2505030120	Brazoria, Galveston, Harris, Jefferson, Orange	0.8021
Coating: Sheet Strip Coil - RE Imp.	2401050000	Harris	0.9709
Major Bakeries	2302050000	HGA NAA	0.2987
Landfills 9%	2620000000	HGA and BPA NAAs	0.2944
Leaking Underground Storage Tanks 9%	2660000000	COAST Domain	0.0000

Note: RE -- Rule Effectiveness NAA -- nonattainment area

HGA -- Houston/Galveston BPA -- Beaumont/Port Arthur

As an example from Table 18, all of the Treatment, Storage, and Disposal Facilities (TSDFs) in the entire COAST domain are expected to have their VOC emissions controlled with 93% efficiency (thus, a control factor of 0.07) prior to the year 2007. Again, the emissions were first grown to the projected year, and then the controls were applied that will take effect between 1993 and 2007. Hence, as Table 19 shows, the emissions before controls were applied are equal to the emissions after being projected (Table 17). Table 19 lists total county and region VOC emissions after the controls were applied. As with point sources, no NO_x controls were applied, nor were control factors applied to offshore sources. At this point, these emissions were ready for input to the UAM.

Table 19. Total Area Source Emissions by Region within the COAST Domain

Before and After Controls were Applied

Region	Projected 2007 (tons/day)			
	Before Controls		After Controls	
	NO_x	VOC	NO_x	VOC
Brazoria Co.	19	26	19	23
Chambers Co.	18	17	18	16
Fort Bend Co.	9	19	9	16
Galveston Co.	33	30	33	26
Harris Co.	181	244	181	197
Liberty Co.	5	12	5	11
Montgomery Co.	8	25	8	22
Waller Co.	2	5	2	5
HGA NAA	**276**	**378**	**276**	**318**
Hardin Co.	3	7	3	7
Jefferson Co.	30	33	30	30
Orange Co.	8	10	8	9
BPA NAA	**42**	**51**	**42**	**46**
HGA/BPA NAAs	**317**	**428**	**317**	**364**
TX counties	422	969	422	885
LA parishes	52	55	52	53
TX+LA	**474**	**1024**	**474**	**938**
Offshore	136	17	136	17
COAST Domain	**445**	**1041**	**445**	**805**

Notes: NAA -- nonattainment area

HGA -- Houston/Galveston

BPA -- Beaumont/Port Arthur

Biogenic Sources

Essentially the same biogenic emission inventory files were used for future year (2007) modeling as for the base case (1993) modeling. It was assumed that the biogenic EI will remain approximately constant between the years 1993 and 2007; hence, no growth factors were applied to the biogenic sources. It was also not feasible to apply controls to these sources.

o) Future Year Modeling

After the projected 2007 EI for the September 8-11, 1993 episode had been quality assured and processed into a model-ready input format, the next step in the attainment demonstration modeling process was to run the UAM-V using this projected inventory, along with the meteorological data files used in the base case modeling. This modeling uses boundary conditions derived from regional modeling (using the 2007 OTAG inventory) described earlier in this document under the heading "Boundary Conditions." The future case modeling provides an assessment of what ozone levels would have been expected during the episode, had emissions been at the predicted 2007 levels.

Figures 26 through 29 show the modeled maximum daily 1-hour ozone concentrations in the Houston/Galveston and Beaumont/Port Arthur areas for September 8-11, 1993, with emissions projected to 2007. Areas having peak daily 1-hour ozone concentrations at or below the 1-hour standard are shown in white, while areas having peak ozone levels above the standard are shown as shaded. All four figures clearly show areas having ozone concentrations well above the 1-hour standard of .12 parts/million (or 125 parts/billion), indicating that reductions to the 2007 projected inventory will be required to demonstrate attainment of the standard.

Figure 26--Daily Max 9/8/93

Figure 27--Daily Max 9/9

Figure 28--Daily Max 9/10

Figure 29--Daily Max 9/11

(1) Reduction Scenario Modeling

Once the future year “base” modeling was completed, commission modeling staff began investigating the type and level of reductions which would be necessary to bring the Houston/Galveston nonattainment area into attainment of the 1-hour standard for ozone. Modeling at first was conducted with reductions applied to the entire COAST modeling domain, to identify the classes of sources (point, mobile, area) and ozone precursor pollutants (VOC and/or NO_x) where reductions would be most effective in attaining the ozone standard. Modeling was then conducted with reductions applied to specific geographic sub-regions to assess whether or not reductions tailored to the specific sub-regions would be more effective for reaching attainment than would broadly applied reductions. Finally, modeling was conducted to find the levels of reductions required to reach attainment, when the reductions were applied only within the 8-county Houston/Galveston nonattainment area.

Domain-wide Reductions

In this first phase of reduction strategy modeling, staff applied reductions to anthropogenic VOC, NO_x, and combinations of VOC and NO_x emissions across the entire COAST modeling domain. These model runs were used to evaluate the relative efficacy of NO_x-only, VOC-only, and combined NO_x-VOC reductions in reducing ozone, when such reductions are applied domain-wide. Table 20 summarizes the modeling runs performed with domain-wide reductions applied to anthropogenic NO_x and VOC. An “X” in a cell indicates that a run was performed with the indicated NO_x and VOC reduction.

Table 20 Summary of Anthropogenic VOC and NO_x Reductions Modeled (Based on 2007 Projected EI)

Anthropogenic NO_x Reduction (%)	Anthropogenic VOC Reduction (%): 0	5	10	25	50	75	100
0	X		X	X	X	X	X
5		X					
10	X						
25	X			X	X	X	X
50	X			X	X	X	X
75	X			X	X	X	X
100	X			X	X	X	X

A second series of model runs was conducted to determine the effectiveness of domain-wide reductions applied to point source NO_x emissions, both by itself and in combination with reductions to anthropogenic VOC. Table 21 summarizes the modeling runs performed with domain-wide reductions applied to point source NO_x and VOC emissions. As in the preceding table, an "X" in a cell indicates that the indicated combination of VOC/NO_x reductions was modeled. A "Y" in a cell indicates a model run which is relevant to the analysis of point source NO_x reductions, but was already listed (combinations involving 0% point source NO_x reductions are identical to the combinations involving 0% total NO_x, since in both cases, no NO_x reductions are applied).

Table 21 Summary of Anthropogenic VOC and Point Source NO_x Reductions Modeled (Based on 2007 Projected EI)

Point Source NO_x Reduction (%)	Anthropogenic VOC Reduction (%): 0	5	10	25	50	75	100
0	Y		Y	Y	Y	Y	Y
5		X					
10	X						
25	X			X	X	X	X
50	X			X	X	X	X
75	X			X	X	X	X
100	X			X	X	X	X

In addition to the two sets of model runs described above, modeling was conducted with domain-wide reductions applied to on-road mobile source NO_x emissions, area source (including off-road mobile sources) NO_x emissions, and combined mobile and area source NO_x emissions. One additional run was performed assuming an 85% reduction to electric utilities across the modeling domain. In these sets of model runs, no VOC reductions were applied. Table 21 summarizes the modeling runs performed with domain-wide reductions applied to mobile, area, combined mobile and area, and electric utility source NO_x. Following the convention established earlier, model runs previously reported are marked with a "Y", while those not previously reported are marked with an "X".

Table 22 Summary of Mobile, Area, and Combined Mobile+Area Source NO_x Reductions Modeled (Based on 2007 Projected EI)

	NO_x Reduction (%)					
NO_x Source	0	25	50	75	85	100
Mobile	Y	X	X	X		X
Area	Y	X	X	X		X
Mobile+Area	Y	X	X	X		X
Electric Utility	Y				X	

Each of the modeling runs discussed in this section is described in Appendix E, *Modeling Results*, which includes a complete listing of modeling performed using the 2007 projected EI.

Geographic Reduction Strategy Modeling

The second phase of modeling consisted of applying reductions of anthropogenic VOC and NO_x in selected geographic subregions within the domain. The purpose of this modeling was to determine whether geographically targeted reductions would provide more ozone benefit than would reductions applied uniformly across the domain, or across the nonattainment area. For example, one question was "Would NO_x reductions applied only in rural areas be effective in reducing peak ozone concentrations?" Another was "How effective would reductions to mobile source VOC emissions in the Houston urban core be in reducing ozone?" To answer these and other questions, a large number of model runs were conducted with reductions applied in each of seven geographic regions, described in Table 23. Figure 30 is a map of the combined Houston/Galveston and Beaumont/Port Arthur 11-county area with each of the seven geographic sub-areas labeled.

Table 23. Sub-Regions Used in Geographic Reduction Strategy Modeling

Sub-Region Name	Description
HGA Nonattainment Area	The eight counties comprising the Houston/Galveston Nonattainment Area: Harris, Galveston, Liberty, Fort Bend, Montgomery, Brazoria, Waller, and Chambers.
BPA Nonattainment Area	The three comprising the Beaumont/Port Arthur Nonattainment Area: Jefferson, Orange, and Hardin.
Houston Urban Core	The portion of Houston bounded on the west by Highway 6, the north and east by Beltway 8, and the south by the Harris County line, but excluding the Houston Ship Channel Area (see map).
Houston Ship Channel Area	The industrialized area along the Houston Ship Channel, including the Baytown and Bayport industrial areas (see map).
Texas City Industrial Area	The heavily industrialized portion of Galveston County including most of Texas City (see map).
BPA Urban and Industrial Area	The industrial and urban areas of Jefferson and Orange Counties, including Beaumont, Port Arthur, and Orange (see map).
HGA/BPA Rural Nonattainment Area	The HGA/BPA Nonattainment Area, excluding the Houston Urban Core, the Texas City Industrial Area, The Houston Ship Channel Area, and the BPA Urban and Industrial Area (see map).

Figure 30--Map of HGBPA Area

Overall, a total of 69 geographic strategy modeling runs were conducted. Table 24 lists the specific source/pollutant reduction combinations tested for each area. In nearly all cases, reductions were applied in multiples of 25%, so specific reduction levels are not listed here (a description of each geographic modeling run performed is included in Appendix E, *Modeling Results*).

Table 24 Geographic Reduction Strategy Model Runs (Based on 2007 Projected Emissions)

Sub-Region	Source/Pollutant Reductions Modeled
HGA Nonattainment Area	Total anthropogenic NO_x Total anthropogenic VOC Combined anthropogenic NO_x and VOC (in equal percentages)
BPA Nonattainment Area	Total anthropogenic NO_x Total anthropogenic VOC Combined anthropogenic NO_x and VOC (in equal percentages)
Houston Urban Core	Mobile source VOC Mobile source NO_x Area source NO_x Combined Mobile + Area Source NO_x
Houston Ship Channel Area	Point source NO_x Point source VOC
Texas City Industrial Area	Point source VOC
BPA Urban and Industrial Area	Point source NO_x Point source VOC
HGA/BPA Rural Nonattainment Area	Point source NO_x Point source NO_x combined with 75% anthropogenic VOC reduction

In addition to the runs listed in Table 24, one run was conducted wherein NO_x from electric utilities outside the counties of Harris, Galveston, and Jefferson were reduced by 85%.

Reduction Target Modeling

The last phase of the reduction scenario modeling involved determining the appropriate levels of reductions to VOC and/or NO_x emissions required to bring the Houston/Galveston area into attainment of the ozone standard. In this phase, reductions were applied to all anthropogenic sources within the 8-county nonattainment area only. Because modeling in the first and second phase had indicated that 1) NO_x reductions would be necessary to reach attainment, and 2) NO_x reductions alone would cause peak ozone concentrations to increase on some days, unless accompanied by VOC reductions, the first task in this phase was to determine the level of VOC reductions which would be sufficient to mitigate this predicted rise in peak ozone concentrations (known in modeling terminology as a "disbenefit"). Once the required VOC reduction was established (at 15%), the second task was to determine the level of NO_x reduction required to bring the area into attainment. This was accomplished by running the model with NO_x reductions at 5% intervals, starting at 10% and ending at 100%. Table 25 lists the model runs conducted to determine the reduction targets for VOC and NO_x. These model runs are also described in Appendix D, *Modeling Results*.

Table 25: Summary of Anthropogenic VOC and NO_x Reductions in 8-County Area Modeled to Establish Reduction Targets (Based on 2007 Projected EI)

Anthropogenic NO_x Reduction (%)	Anthropogenic VOC Reduction (%)			
	0	10	15	20
0	Y			
10		X		
15	X		X	
20			X	X
25	Y	X	X	X
30			X	X
35			X	
40			X	
45			X	
50	Y		X	
55			X	
60			X	
65			X	
70			X	
75	Y		X	
80			X	
85			X	
90			X	
95			X	
100	Y		X	

(2) Conclusions Based on Reduction Strategy Modeling

This section summarizes conclusions derived from the three phases of modeling described above. First, general conclusions which were presented to the Commission at the November 6, 1997 work session are discussed. Additional discussion of the geographic analysis modeling follows, and this section concludes with a discussion of the reduction target modeling which was performed to pinpoint specific levels of VOC and NO_x reductions which demonstrate attainment of the standard.

General Conclusions

This section summarizes the general conclusions drawn from the three phases of reduction strategy modeling described above, as related to the Houston/Galveston nonattainment area.

> ***VOC reductions alone will reduce maximum ozone concentrations, but will not be sufficient for attainment.***

This conclusion is illustrated by the line graph in Figure 31, which shows the maximum 1-hour ozone concentration modeled within the eight county nonattainment area for each day of the September 8-11, 1993 episode, with projected 2007 emissions. The horizontal axis shows various levels of VOC reductions, while the vertical axis shows peak ozone concentration in parts per billion (ppb). The dashed line is at 124 ppb, the 1-hour ozone standard. For a reduction level to show attainment, the line for each day's peak ozone would need to intersect the dashed line. Since none of the lines are seen to intersect the dashed line, then clearly VOC reductions alone will not be sufficient to bring the area into attainment.

Figure 31

Total NO_x reductions alone can achieve attainment in the Houston/Galveston nonattainment area, but only with overall reductions of 75% and above from point, mobile, and area sources. Decreases in ozone concentrations are relatively small until overall NO_x reductions reach 50% and above.

Figure 32 shows maximum ozone for each day in the episode, for varying levels of NO_x reductions. For the 8th, 9th, and 10th, the lines are seen to intersect the standard in the range of 80% NO_x reduction, while on the 11th, the maximum concentration does not intersect the standard until nearly 100% reduction. However, an examination of the graph indicated that moving from 75% to 100% NO_x reduction reduces ozone very little (this situation is caused by high ozone levels at the edge of the 8-county nonattainment area which do not respond to local reductions). Commission staff thus have concluded that on the 11th, NO_x reductions in the 75-80% range are sufficient for the local area, with the possibility that attainment will ultimately depend on reductions outside the 8-county area.

Figure 32

For the Houston/Galveston nonattainment area, NO_x reductions from point sources alone are not sufficient for attainment, nor are they effective alone in reducing ozone. NO_x reductions from mobile and area sources are more effective than from point sources, but are not sufficient for attainment.

Figure 33 compares the response of domain-wide point source NO_x reductions to non-point source NO_x reductions on the 8th, which is fairly typical of the four episode days modeled. Figures for the remaining episode days are provided in Appendix D, *Modeling Results*. Point source NO_x reductions alone are predicted to do little to improve peak ozone concentrations, and in fact on some days NO_x reductions actually cause a slight disbenefit. For every day, as is shown for the 8th, the non-point source NO_x reductions are more effective than point source NO_x reductions, even though point sources account for about half of total NO_x emissions in the COAST domain. Neither point nor non-point source NO_x reductions alone are sufficient for the area to reach attainment.

Figure 33

Combined reductions in the 10-20% range of both point source NO_x and total VOC decrease the areal extent of ozone exceedances.

It is often useful to examine measures of ozone pollution that are more comprehensive than peak ozone concentration. One such measure is the spatial extent, in square kilometers (km^2), of the area experiencing ozone levels that exceed a threshold. Figure 34 shows the spatial extent of peak ozone above 120 ppb on the 8th, for point source NO_x reductions alone, and also for point source NO_x reductions combined with VOC reductions. In the case of point source NO_x reductions alone, an initial disbenefit is seen, followed by a reduction in areal extent of ozone exceeding 120 ppb when reductions reach the 50% level. In contrast, the peak ozone concentration remained nearly constant on the 8th for all levels of point source NO_x reductions. Appendix E, *Modeling Results*, contains figures analogous to Figure 34 for the remaining episode days.

When point source NO_x reductions are combined with VOC reductions, the NO_x disbenefit is no longer seen at any range of reductions, and the benefits are higher at all reduction levels. It is important to remember, however, that a 10% reduction in a combined reduction scenario represents a higher level of control than a 10% for a single pollutant, since in the combined reduction, the 10% reduction is applied to *both* pollutants.

Figure 34

For the Houston/Galveston nonattainment area, reductions of VOC and/or NO_x in the 10-20% range would meet the test for a §182(f) exemption, but reductions above 50% would not. Modeling supporting the original §182(f) exemption showed disbenefits at 50% NO_x reduction levels, whereas the current modeling shows benefits beyond this reduction level.

An area can qualify for a §182(f) exemption provided it can show that a VOC-only reduction strategy is more effective than either a NO_x-only strategy or a combined VOC/NO_x strategy. Figure 35 shows that for reduction levels in the 10-25% range, VOC is the best strategy on the 8th (additional figures provided in Appendix E show this to be the case for the other three days as well). However, at reduction levels greater than 50%, a NO_x-based strategy becomes the best strategy; hence, Houston/Galveston could not qualify for a §182(f) exemption at reduction levels required to reach attainment. While earlier modeling showed a strong disbenefit for reduction levels in the 50% range, the current modeling, based on much better input data and developed using the most recently available state-of-the-science modeling tools, shows a benefit at this reduction level.

Figure 35

Attainment of the new 8-hour standard will require more NO_x reductions than for the current 1-hour standard.

Figure 36 shows 8-hour peak ozone concentrations at various reduction levels of VOC and NO_x in the 8-county nonattainment area for September 8. The graph illustrates the difficulty posed by the new standard; according to the modeling, even with all anthropogenic emissions removed from the 8-county area, the area could still not meet the 8-hour standard of 84 ppb (as above, this situation is attributable to sources outside the 8-county area). Figures for the remaining days of the episode, included in Appendix D, *Modeling Results*, indicate that the 8-hour standard could be achieved on two days (the 9th and 10th), but might require NO_x reductions of over 90%.

Figure 36

At levels of NO_x reduction of 50% and above, NO_x substitution for VOC may be acceptable under EPA's ROP requirements.

Even though VOC reductions may be more effective than NO_x reductions for smaller reduction levels, the modeling indicates that NO_x reductions of over 50% are required to reach attainment. But at the reduction levels required to bring peak ozone levels down to the standard, which are well above 50%, NO_x reductions are clearly more effective at reducing ozone than are VOC reductions. Therefore, substituting NO_x for VOC appears to be allowable under the EPA's ROP requirements. EPA Region VI staff has indicated that the NO_x substitution would be allowable.

Additional Observations Based on Reduction Strategy Modeling

The second phase of the modeling (geographic reduction strategy testing) was inconclusive. The modeling staff generated many plots and graphics to assess the effects of reductions in specific regions on ozone levels in those regions and in other areas. The analysis did not reveal any clear indications that reductions in one or more of the subregions would be more beneficial than would uniformly-applied reductions. In particular, reductions to utilities in the HGA/BPA Rural Area (see Figure 30) did little to reduce ozone levels in any part of the Houston/Galveston nonattainment area. Other geographic reduction strategies showed benefits in some areas, but no strategy showed a clear superiority in reducing overall ozone levels in the nonattainment area.

Definition of Reduction Targets

To establish a level of VOC reduction that would mitigate any short-term NO_x disbenefit, commission staff performed a series of model runs wherein VOC was reduced to a certain level, then NO_x reductions were varied in the range of 10-50%. A NO_x disbenefit of less than 5 ppb was considered insignificant, since the standard is stated as .12 parts per million (ppm), and a disbenefit of less than 5 ppb (which equates to .005 ppm) is within the round-off tolerance of the standard. That is, .12 ppm $\pm \epsilon$ would round to .12 ppm for any value of $\epsilon < .005$ ppm.

Table 26 shows the peak simulated 1-hour ozone concentration for selected VOC and NO_x reduction levels for September 11 as an example. When no VOC reductions were assumed, this episode day showed the largest NO_x disbenefit (almost 9 ppb) of the four modeled days. The disbenefit can be seen in Table 26 by comparing peak ozone values assuming zero anthropogenic NO_x reduction and zero anthropogenic VOC reduction (181.7 ppb) to peak ozone with a 25% NO_x reduction and zero anthropogenic VOC reduction (190.6 ppb). However, if the first 15% reductions are applied to both VOC and NO_x (resulting in 180.7 ppb peak ozone), then further NO_x reductions are seen to produce relatively smaller disbenefits, all of which are less than 5 ppb (shaded column in the body of Table 26). Thus, commission staff concluded that if VOC and NO_x are both reduced by 15%, then additional NO_x reductions will not produce an appreciable disbenefit.

Table 26: Peak Simulated 1-Hour Ozone Concentrations in Houston/Galveston Nonattainment Area, September 11 with Emissions Projected to 2007

Anthropogenic VOC Reduction (%)

Anthropogenic NO_x Reduction (%)	0	10	15	20
0	181.7			
10		181.2		
15			180.7	
20			181.6	179.7
25	190.6	186.3	184.1	181.7
30			184.9	182.9
35			184.1	
40			182.6	

Once a 15% VOC reduction target had been established as sufficient to mitigate the NO_x disbenefit, the model was then executed with NO_x reductions starting at 10% and going all the way to 100% in 5% intervals. Figure 37 shows the modeling results for each of the four episode days. The figure shows that NO_x reductions in the 80-85% range will still be necessary to show attainment of the one-hour standard, even with the assumed 15% VOC reduction. However, the graph indicates that no significant disbenefits occur at lower reduction levels. In summary, the reduction target modeling indicates that a strategy of reducing VOC and NO_x together by 15% each from projected 2007 levels, followed by NO_x-only reductions of (an additional) 65-70%, will lead to attainment of the standard while producing no appreciable disbenefits.

Figure 37

p) Reasonable Achievable Target Modeling

(1) Introduction

While the Urban Airshed Model is widely accepted as a useful planning tool which provides directional guidance for developing control strategies, the model's results contain significant levels of uncertainty. Uncertainties in the meteorological characterization, EI, and future growth projections, together with the inherent limitations characteristic of even highly sophisticated models, combine to produce a significant degree of uncertainty in the model's future projections. The commission believes that long-term modeling predictions must be followed periodically with mid-course evaluations and, if necessary, adjustment of the chosen control path. Therefore, the reduction targets established in the preceding section must be viewed only as interim targets, subject to revision in subsequent analyses.

The commission believes that NO_x reductions in 80-85% range represent the level of control required under the worst-case scenario, and that attainment may be possible with more achievable reduction targets. The rationale for this belief is based on comparisons made between VOC/NO_x ratios derived from ambient air sampling and similar ratios derived from the EI used in the COAST modeling (see *Use of PAMS Data to Evaluate the Texas COAST Emission Inventory*, prepared by Sonoma Technology, Inc. Copies may be obtained from the commission upon request). Ratios from ambient air sampling may range from two to six times as high as ratios predicted from the modeling inventory, suggesting that the modeling inventory may have an over-abundance of NO_x, a deficiency of VOC, or both.

The consequence of a low VOC/NO_x ratio in the modeling inventory would be that the modeled peak ozone would not respond favorably to NO_x reductions except at very large reduction levels. If, in reality, the VOC/NO_x ratio were higher than that used in the model, then NO_x reduction targets lower than those established through modeling might be sufficient to achieve attainment. Because the VOC/NO_x ratio characteristic of the modeling inventory is quite low compared to ambient ratios, reduction targets predicted by the model may be more stringent than necessary, and thus the base inventory constitutes what may be considered to be a "worst case" scenario. To see what levels of reduction would be necessary if the ambient air ratios more closely match the actual conditions for this episode, commission staff established two "alternative inventories." The model was then executed using the alternative inventories to calculate reduction targets. The reduction targets so derived may be viewed as lower bounds on the required reduction levels.

A second, but equally important, reason for developing the alternative inventories is to test the directional guidance developed using the base 2007 inventory: If one of the alternatives were in fact true, would the reduction path developed using the 2007 base inventory still be the best choice, or would a VOC-based strategy provide a more efficient path to attainment? If the alternatives give the same directional guidance as the base (even though the actual reduction targets may differ), we can be more confident that the reduction strategy developed with the base inventory will provide an effective path to attainment.

In the Interim Implementation Guidance, EPA says that states may use their *Guidance on Use of Modeled Results to Demonstrate Attainment of the Ozone NAAQS*, which was published in June 1996. Section 5.3.6 of that guidance states that:

> *Other types of analyses, in addition to those described, may be used to support a weight of evidence determination. The rationale underlying use of such an analysis, results obtained and*

how these results support or do not support a conclusion that attainment is likely need to be documented.

The State of Texas has chosen to look at several elements described in the guidance, and has also chosen to investigate other lines of evidence as outlined above. When these other lines of evidence have been pursued, the SIP provides the required rationale underlying the use of these analyses, the results obtained, and how these results support the conclusion that attainment is likely for the Houston/Galveston area, as directed in the guidance.

The attainment guidance also discusses that the state should provide for a mid-course review and, if necessary, a correction. The state plans to conduct control strategy testing before the submittal of control strategies in late 2000. Additionally, the state plans to submit a SIP for the 8-hour attainment demonstration in 2003. This will be another opportunity for the state to examine growth, control strategies, and other factors leading to modeling uncertainty, and to use the latest state-of-the-science modeling techniques to better examine Houston/Galveston air quality. The state believes that these two submittals will constitute appropriate mid-course corrections.

(2) Alternative EI Modeling

The two alternative emissions inventories used in this exercise were previously discussed in the Performance Evaluation section of this SIP, where base-case sensitivity analyses showed that model performance would have been generally acceptable had either alternative been used to develop the base case (although their performance was not as good as was seen using the actual base case inventory). Future-year versions of each alternative were created by applying the adjustments described in Table

PEX in the Performance Evaluation section to the 2007 base inventory. First, the model was executed with each alternative assuming COAST domain-wide reductions of 0%, 25%, 50%, 75% and 100% applied to VOC, NO_x, and combined VOC/NO_x emissions. The results for September 8 using Alternative 1 and Alternative 2 are shown in Figure 38 and 39, respectively (figures for the remaining episode days are provided in Appendix E). These figures indicate that under Alternative 1 the model is much more responsive to VOC controls than it is using the base 2007 inventory, although VOC reductions alone will still not lead to attainment with either alternative. With Alternative 1, removal of all anthropogenic VOC emissions is almost sufficient to reach the standard, and on the remaining episode days does actually drop peak ozone below the standard - see Appendix E. Comparing Figures 38 and 39 with Figure 31 in the previous section also indicates that 1) at 0% reduction, peak predicted ozone is lower with either alternative than with the base 2007 inventory, and 2) significantly less NO_x reduction is required to reach attainment with either alternative than with the 2007 base inventory.

Figure 38

Figure 39

The model was then executed with each alternative, after applying VOC reductions of 15% combined with NO_x reductions of 50%, 60%, 70%, and 80% in the 8-county Houston/Galveston nonattainment area. The goal of this aspect of the modeling was to determine the NO_x reduction necessary to reach the standard under either alternative. Figures 40 and 41 show modeling results for each episode day under Alternative 1 and Alternative 2, respectively.

Figure 40 indicates that under Alternative 1, NO_x reductions necessary to achieve the standard range from less than 60% on September 9th to slightly more than 70% on the 10th. On the 8th, the day of highest predicted peak ozone using the base 2007 inventory, a reduction of between 65 and 70% would achieve the standard. Based on this alternative, NO_x reductions of 70% would thus suffice to achieve (or very nearly achieve) attainment on all four days.

Figure 41 shows that somewhat higher reductions of NO_x would be necessary under Alternative 2. In this case, reduction targets range from just over 60% on the 9th to over 75% on the 10th, with a reduction of around 70% indicated for the 8th. Based on this alternative, NO_x reductions of between 75 and 80% would thus suffice to reach attainment on all four days.

Figure 40

Figure 41

(3) Regional Reduction Scenario Modeling

The commission also derived 2007 reduction targets for the Houston/Galveston nonattainment area under the assumption of a regional reduction strategy. As was discussed earlier, on at least one modeled episode day, September 11, the area is apparently influenced by emissions emanating from outside its borders. On this day, modeled NO_x reductions of 80% (based on the base 2007 inventory) are sufficient bring the peak ozone in the nonattainment area almost to the 124 ppb standard, but the standard is not actually reached until NO_x reductions in excess of 95% are applied, due to high ozone concentrations along the nonattainment area's border. If regional emission levels were reduced, then presumably lower reduction targets for the 8-county nonattainment area would be sufficient to reach attainment.

To test the above hypothesis, commission staff assumed that the OTAG 5c strategy was applied everywhere except the 8-county area, including in the regional domain used to establish the 2007 boundary conditions. The OTAG 5c strategy, consisting of a 60% reduction to elevated NO_x emissions, a 30% reduction to low-level NO_x emissions, and a 30% reduction to all VOC emissions, was used frequently in OTAG's early modeling, and was chosen here because of its familiarity. Reductions are expected in surrounding states by 2007 due to OTAG, federal programs, and attainment planning processes.

The model was executed assuming the regional OTAG 5c strategy, together with a 15% VOC reduction in the 8-county nonattainment area, combined with NO_x reductions in the 8-county area of 50%, 60%, 70%, and 80%. Figure 42 shows the results for September 8, along with the base model results. The OTAG 5c reductions are seen to decrease peak ozone only about 5 ppb from the 2007 base, but the 5c curve reaches the attainment level at about 5% less NO_x reduction than does the base. On September 9th, shown in Figure 43, the required NO_x reduction is lowered by about 3%, while on the 10th, (Figure 44) the 5c line has not crossed the attainment level at 80% (looking at the 140 ppb horizontal line indicates that the 5c strategy lowers the NO_x reduction required to reach 140 ppb by about 5%). In Figure 45, the 5c strategy for September 11th appears to have little effect on peak ozone concentration; however, the 5c curve reaches the standard at 80% NO_x reduction while the base 2007 curve does not reach the standard until past 95%.

Overall, while the OTAG 5c strategy is predicted by the modeling to have minimal effect on peak modeled ozone concentrations, it does provide significant relief in the level of NO_x reductions required to reach attainment, ranging from 3% to more than 15%.

Figure 42

Figure 43

Figure 44

Figure 45

(4) Lower Bound on Required NO_x Reductions

Combining the results of the alternative inventory modeling with the OTAG 5c strategy modeling, we can develop a reasonably achievable reduction target under the best-case scenario (i.e. the case where the actual inventory is in reality similar to Alternative I, *and* regional reductions on the order of the OTAG 5c occur by 2007). Assuming the Alternative I inventory, the modeling indicates that 70% NO_x reduction is a reasonable lower bound, while modeling assuming the 5c strategy indicates that the reduction target may be decreased by 3 to 5% or more. Combining the results linearly[2] yields a lower bound of between 65 and 67%.

Since the Alternative I inventory is based at least in part on measured data, and since some level of regional reductions are likely to be made before 2007, then NO_x reductions at a level of 65%, together with a 15% VOC reduction have a reasonably good chance of bringing the area into attainment by 2007. However, should the base 2007 inventory prove to be correct, and no regional reductions occur, the modeling indicates that the area would fail to attain the 1-hour standard by its attainment date with these reductions. Table 27 illustrates that even in this latter "worst case," a 15% VOC reduction combined with a 65% NO_x reduction would lead to a very significant improvement in air quality. Besides showing the before and after maximum modeled ozone concentrations, the table presents before and after comparisons using four additional air quality metrics which provide more broad-based measures of overall air quality within the Houston/Galveston 8-county nonattainment area:

[2]Because the UAM is highly nonlinear, it is possible that results may not be additive. The only sure way to determine the combined effect of regional reductions plus an alternate inventory would be through additional modeling, which was not performed in time to be included in this SIP.

- **Max O_3 - 120 ppb** This metric is the amount, in ppb, by which the peak modeled ozone in the 8-county region exceeded 120 ppb. If 120 ppb is assumed to constitute a threshold above which 1-hour average ozone levels are unhealthy, then this metric represents the worst single occurrence of unhealthy ozone on a particular day.

- **Area > 120 ppb** This metric is the area, in square kilometers, of the portion of the nonattainment area exposed to unhealthy levels of ozone at any time during an episode day. It is calculated by identifying all the modeling grid cells which exceeded the 120 ppb threshold at any time during the day, then summing the area of each identified grid cell.

- **Area-Hours > 120 ppb** This metric is similar to the above, but also counts the hours each grid cell spends above the 120 ppb threshold. It is calculated as above, except that each identified grid cell is counted a number of times equaling the number of hours that the concentration in that cell exceeded the 120 ppb threshold.

- **Exposure > 120 ppb** This metric is similar to area-hours, but before each grid cell hour is counted, it is first weighted by its level of unhealthy ozone, i.e. the amount by which the modeled concentration in the grid cell at that hour exceeded 120 ppb. This metric provides a very comprehensive measure of the air quality within the nonattainment area.

In-depth descriptions of the four metrics discussed above, as well as several others, are given in Ozone Metrics for Attainment Demonstrations by Smith and Durrenberger, published in the *Proceedings of the Air & Waste Management Associations's 90th Annual Meeting & Exhibition*.

Table 27: Improvements in Air Quality Measures in the Houston/Galveston Nonattainment Area under Base 2007 Assumptions, with 15% VOC and 65% NO_x Reductions in the Nonattainment Area

Episode Day	Metric	Units	2007 Base	15% VOC + 65% NO_x Reduction	Percent Change
9/8	Max O_3 Concentration	ppb	191.4	156.0	
	Max O_3 - 120 ppb	ppb	71.4	36.0	-49.58
	Area > 120 ppb	km^2	8640	4192	-51.48
	Area-Hours > 120 ppb	km^2 hr	30944	13712	-55.69
	Exposure > 120 ppb	ppb km^2 hr	433331	138992	-67.92
9/9	Max O_3 Concentration	ppb	172.3	146.4	
	Max O_3 - 120 ppb	ppb	52.3	26.4	-49.52
	Area > 120 ppb	km^2	5088	1520	-70.13
	Area-Hours > 120 ppb	km^2 hr	17744	4000	-77.46
	Exposure > 120 ppb	ppb km^2 hr	256332	34930	-86.37
9/10	Max O_3 Concentration	ppb	176.8	143.8	
	Max O_3 - 120 ppb	ppb	56.8	23.8	-58.10
	Area > 120 ppb	km^2	8464	2128	-74.86
	Area-Hours > 120 ppb	km^2 hr	28384	5264	-81.45
	Exposure > 120 ppb	ppb km^2 hr	351261	44716	-87.27
9/11	Max O_3 Concentration	ppb	181.7	158	
	Max O_3 - 120 ppb	ppb	61.7	38	-38.41
	Area > 120 ppb	km^2	6112	3056	-50.00
	Area-Hours > 120 ppb	km^2 hr	18736	5728	-69.43
	Exposure > 120 ppb	ppb km^2 hr	380342	65727	-82.72

Table 27 shows that, even under the worst-case scenario (the 2007 base inventory), reductions of 15% in VOC and 65% in NO_x are seen to produce very substantial improvements in air quality, reducing the area suffering levels of ozone over 120 ppb by 50 to 75%, area-hours by 55 to 82%, and total exposure by 68 to 87%.

(5) Conclusions

Taking the base 2007 inventory to represent the worst case, and the combination of regional controls with the Alternative I inventory to represent the best case, the modeling indicates that a 15% VOC reduction combined with NO_x reductions in the range of 65-85% will bring the Houston/Galveston area into attainment by 2007. The most likely situation is that the actual levels of NO_x reductions required will be somewhere between the best and worst cases (more than 65% but less than 85%). The commission will continue to examine the issues surrounding the quality of air along the Texas Gulf Coast, and will continue to improve upon its methodologies to more accurately characterize air quality in the region through modeling. Before regulations are adopted in 2000 by the state, the state intends to perform control strategy testing using the Urban Airshed Model. The state believes that this will provide a greater confidence that this strategy will lead to attain the ozone NAAQS in Houston/Galveston. Further, the 8-hour attainment demonstration due in 2003 will provide the commission with an opportunity to refine the reduction targets necessary to bring the area into attainment.

A second important conclusion that can be drawn from the alternative inventory modeling exercises is that directional guidance for reduction strategies would not change if either alternative inventory were true. While both alternatives, particularly Alternative I, do show more favorable response to VOC controls than the 2007 base case, large NO_x reductions would still be required in any case. Although the relative effectiveness of VOC vs. NO_x reductions in the Houston/Galveston nonattainment area was not specifically evaluated under the OTAG 5c assumptions, it is seen that a strategy of reducing VOC by 15% in combination with substantial NO_x reductions would provide a path to attainment in this case as well.

q) Observation-Based Weight of Evidence Determination

(1) Introduction

As discussed in previous sections, photochemical modeling has been utilized to establish a reasonable precursor reduction strategy (type and quantity of ozone precursors) needed for attaining the 1-hour ozone NAAQS. As another approach, monitoring data analyses can be performed to determine what types of reductions of precursors would be effective in reducing ozone. If the monitoring data approach provides guidance consistent with the modeling results, confidence is added to the direction taken with the precursor reduction strategy. A discussion is provided below on various ambient data analyses and the implications for control strategy development for Houston/Galveston.

There are a number of techniques that have been classified as observational modeling. Observation based modeling is defined here as analyses of monitoring data to determine whether VOC or NO_x emissions should be reduced to control ozone. The scope of these analyses has rapidly evolved, with continued work related to major ozone research studies.

Most of the new observation based modeling methods have been applied to data bases that contain measurements of *all nitrogen oxide compounds* (NO_y), so consequentially these new approaches depend upon having measurements of NO_y. In Texas, NO_y has not been measured by the routine continuous monitors, nor was it measured during the COAST Study. In addition to NO_y measurements, observation based analysis methods require nitrogen oxide (NO), nitrogen dioxide (NO_2), and NO_x measured with a high degree of accuracy in the range below 10 ppb. In Texas, data are available for NO and NO_x. Because the calibration methods used were designed to produce data for comparison with the NAAQS for NO_2, there were no calibration points established between zero and 100 ppb. The resulting uncertainty in the range below 10 ppb thus limits the usefulness of the data for observational methods. The absence of NO_y and true NO_2 data also limits the interpretation of observation based analyses, but it is still useful to examine the results of these analyses, keeping the limitations in mind.

Observation based modeling methods are inherently limited to analysis of data for the year that the monitoring data was collected. This means that they indicate the effect that controls likely have if applied to conditions close to those that existed when the monitoring was performed. For this reason, the results of observational analyses cannot be used to determine the impact of emission changes after substantial emission reductions have already been achieved.

Current views by experts in the field of observation based modeling indicate that analyses of VOC/NO_x ratios are not useful in determining directional guidance for control strategy development, so this approach has not been utilized at the commission. However, another approach - the Smog Production (SP) algorithm - can be applied to the COAST data set and other historical monitoring data, although it yields some uncertainty since NO_x measurements are used instead of the preferred NO_y measurements. Also, the results are uncertain due to the uncertainty of the NO_x measurement in the low range.

(2) Summary of Results of Application of SMOG Production (SP) Algorithms to the COAST Data

As part of a data analysis contract for the COAST Study, the Smog Production (SP) algorithm was applied by Blanchard, et al., to the COAST data for the major COAST ozone episodes. One version of the SP algorithm was also applied to Houston ozone exceedance data for a number of years to determine whether the results for the COAST episodes were typical of Houston ozone exceedances. These results give directional guidance about the potential effects of controls on the conditions analyzed.

The project's analysis of ozone exceedances from 1988 through 1994 led to the following conclusions:

1. Some locations, generally those closer to industrial and traffic source areas, showed either frequent or consistent VOC limitation of ozone peaks. This means that VOC controls would be more effective than NO_x controls in reducing ozone. This interpretation is strengthened by the fact that applying the SP algorithm to NO_x instead of NOy data overestimates the amount of NO_x limitation. This means that the conclusion of VOC limitation is a more robust conclusion.

2. Some sites, generally those some distance downwind of sources, showed frequent or consistent NO_x limitation. At these locations, NO_x controls would be more effective than VOC controls in reducing ozone.

3. Where there is VOC limitation, initial reductions in NO_x would be expected to cause an increase in ozone peaks unless there are also initial VOC reductions. At sites with consistent NO_x limitation, initial NO_x reductions are predicted to reduce ozone peaks.

The project's analysis of the COAST episodes is consistent with the analysis of the seven years of ozone exceedances. A copy of the results of applying the SP algorithm to the years 1988-1994, as well as the COAST episodes, is provided in Appendix F, *Application of Smog Production (SP) Algorithms to the Coastal Oxidant Assessment for Southeast Texas (COAST) Data.*

Although the application of the observation based modeling was limited since no NO_y measurements have been made in Texas, the analysis described above corroborates the results found with the photochemical modeling. Both the SP algorithm and the photochemical modeling showed that the response to reductions of VOC and/or NO_x varied over the domain. They both showed that reductions of both VOC and NO_x will be needed to attain the standard. It should be noted that the SP algorithm cannot establish the specific level of reduction needed to attain the standard, nor the effect of a combination of reductions of both VOC and NO_x .

The SP algorithm analysis also indicates that at some locations initial NO_x reductions may cause ozone to increase until large NO_x reductions have been obtained. This result is consistent with the findings from the modeling.

(3) Monitoring Metrics

The purpose of an ozone SIP is to reduce ambient ozone levels below the standard. Since ozone is a pollutant that is formed in the atmosphere, to reduce the ozone, the SIP must identify sources of ozone precursors that can be reduced. Photochemical modeling uses atmospheric chemistry to relate precursor emissions and meteorology to ozone formation. If precursor emissions are reduced, this reduction should cause ambient levels of the precursor to decrease, and if the model chemistry is correct, ozone levels should decrease. Thus, if EI analyses indicate that the emissions of NO_x are decreasing, the same trend should be seen in the monitoring data. Similarly, if VOC is thought to be the precursor to reduce to lower ozone, and if VOC emissions are decreasing, then ozone should decrease. These assumptions about reductions can be tested by analyses of measurements of ozone and ozone precursors. For the Houston/Galveston area the following assumptions were verified by analyses of monitoring data:

1. NO_x emissions were estimated to decrease, and measurements of ambient NO_x decreased.

2. VOC emissions were estimated to decrease, and measurements of ambient VOC decreased.

3. Over the past decade ambient ozone measurements have decreased.

Thus, in the Houston/Galveston area, if ozone precursors are reduced more than at the present rates, then ozone is expected to decrease at a faster rate than in the past. Also if trends in monitored concentrations project ozone to reach attainment of the standard by 2007, then this can be used as an indicator that the standard will attained, provided that the emissions reductions identified by the modeling are implemented. What follows is a summary of analyses that were used to establish the three statements above and projections of trends to the future.

Analyses for metrics that are analogous to those used for modeling were applied to ambient monitoring data obtained in the Houston/Galveston area. To establish a possible trend with historical data, these metrics were analyzed for a period covering several years. It was then possible to project the historical trend lines to the Houston/Galveston attainment year of 2007. The following caveats must be considered when analyzing these projected trends:

1. It is assumed that the emission reduction rate over the future time period will be approximately equivalent to that for the historical time period analyzed.

2. It is assumed that the impact of the emission reductions in the future is approximately equivalent to that for the historical period analyzed.

3. The variability of future meteorology is accounted for in the projected trend line. Due to this variability, the actual values for each year may vary around the trend line.

Due to the large reductions of VOC and NO_x proposed in this SIP, future reductions will be greater than those during the historical period, as per the following considerations:

1. For the period from 1990 to 1996 the reductions of VOC emissions were projected to be at least 15% from the 1990 levels.

2. To meet future ROP goals, the reductions of a combination of NO_x and VOC emissions will have to exceed 3% per year. From 1996 to 1999 VOC will be reduced by 9%, and to provide for

attainment of the 1-hour standard by 2007 VOC will be reduced by an additional 15% along with additional NO_x reductions.

3. To provide for attainment of the 1-hour ozone standard by 2007, between 1999 and 2007 the area will have to have a total reduction of from 65% to 85% NO_x, which is greater than the amounts reduced in the past based on either estimated or measured values.

Overall, then, emission reductions expected through 2007 will be greater than those during the historical period analyzed.

(4) Precursor Trends

Emissions quantified in emissions inventories can vary from year to year due to a number of causes. For example, at a given plant emissions from one year's inventory could differ from those of another year due to:

1. Change in emission approximation techniques,
2. Change in emissions due to changes in operating schedule,
3. Process change, or
4. Elimination of a production unit.

Changes in emission approximation techniques will not change the amount of pollutants that are actually emitted, but could change the numbers reported in the inventory. Changes in the operating schedule could be short term, which could be reflected in monitoring data. However, changes in long term operating schedules might change the annual emissions, but have no effect on the emissions on a given day. Thus, such changes would be expected to show up in monitoring averages taken over a long period such as a season, but not be identified in daily monitored values. Thus, it is difficult to correlate changes in emissions inventories with changes in monitoring data.

(5) Historical NO_x Trends - Emissions and Ambient Data

With acknowledgment of the uncertainties in comparing emissions trends, Figure 46 shows the trends for NO_x EI estimates for on-road and area and non-road sources from 1980 to 1996. The trends in point sources are shown from 1988 to 1996. Trends in earlier emissions are questionable, as there was a significant variation in the estimation methods used prior to 1992 and after 1992.

In the Houston/Galveston area there is limited monitoring data for ozone precursors. A review of the historical monitoring data indicates that from 1980 to 1996 there is sufficient NO_x monitoring data from the Houston East, Clinton Drive and Aldine sites in the Houston area to establish trends. NO_x is a complex mixture of reactive nitrogen oxides, so analysis has been limited to concentrations monitored in during the morning hours of 6:00 to 9:00 am when photochemical activity is minimized. The analysis is also limited to the period from May to October since this is the primary period for photochemical activity.

Figures 47, 48 and 49 show the NO_x monitoring trends from 1980 to 1997 at the Houston East, Aldine, and Clinton Drive monitors. The following are noted for all three sites:

Figure 46

Figure 47

Figure 48

Figure 49

1. The maximum concentration shows a significant downward trend.

2. The trend of the 95th percentile for the measurements does not vary as much as the maximum concentration, but shows a downward trend.

3. The annual average of all NO_x measurements shows a downward trend.

(6) Historical VOC Trends - Emissions and Ambient Data

With acknowledgment of the uncertainties in comparing emissions trends, Figure 50 shows the trends for VOC EI estimates for on-road and area and non-road sources from 1980 to 1996. The trends in point sources are shown from 1988 to 1996. Trends in earlier emissions are questionable as there was a significant variation in the estimation methods used prior to 1988 and after 1988.

In the Houston/Galveston area, there is limited monitoring data for VOC. At the Clinton monitoring site three hour integrated canister samples were collected from 6:00 am to 9:00 am on various days during 1978, 1979, 1980, 1981, and 1982. The averages for these samples are shown in Figure 51. During 1993 and starting in 1997 continuous hourly samples were collected and analyzed with gas chromatography (so called continuous gas chromatography). The averages for total VOC for 1993 and 1997 are included in Figure 51 even though the sampling and analysis techniques have been different. A review of these data show a significant decrease in measured VOC. This trend has continued over the whole time period.

Figure 50

Figure 51

The Houston Regional Monitoring (HRM) Network is a privately funded and owned monitoring network in the Houston area. From the end of 1987 to 1995 HRM has collected 24-hour samples and measured various VOC components in the sample mixture. All of this data is shown in Figure 52. Two very high values found in 1988 and 1992 were excluded. A review of this data and the regression line drawn through the data shows that there has been a reduction in measured VOC of approximately 25% in the area covered by the HRM network. This is a little above an average of 3% per year. Figure 53 shows the location of the HRM sites where samples were collected. The sites are located primarily in the main area of industrial activity in the Houston/Galveston area. However, these sites also measure VOC impacts from significant area sources, non-road mobile sources and on road mobile sources. Details of the analysis are provided in the commission publication *Decrease in Ambient Air Concentrations of Benzene, Toluene, and Total Xylenes in Southeast Texas (TNRCC AS-134, May 1997)*. This publication is provided in Appendix G.

Figure 52

Figure 53

(7) Historical Ozone Trends - Ambient Data

There is an extensive ozone monitoring network in the Houston/Galveston area, with 14 monitors over three counties run by the state or city. The number of monitors and the location has varied over the years, but these locations have been relatively constant since 1987. Trends that involve data affected by variations in meteorology must be developed over a long enough time to minimize the short term variations. The Federal Advisory Committee Act (FACA) Science and Technical Support Work Group has recommended that a minimum of six years of data be utilized to establish trends from air quality monitoring data. Most of the trends analyses have been performed for the period from 1987 to 1997. The following metrics for ozone monitoring data have been analyzed: 1-hour design value, 1-hour areal extent of concentrations greater than 120 ppb, and 1-hour total exposure greater than 120 ppb.

1-hour Design Value

The 1-hour ozone design value for an area is the monitoring metric that corresponds to the domain wide ozone maximum predicted by modeling. The graph of the annual 1-hour design values for ozone from 1982 to 1997 is shown in Figure 54. The year-to-year design values are based on three years of data, so they are not statistically independent. However, in order to express how variable the trend has been since 1982, the formulas for confidence intervals have been applied to the data. Also, the trend line has been extended into the future. Figure 54 includes the lines that define the envelope of the 95% confidence limits for the fit of the trend line to the data. Also included in Figure 54 are the lines that define the envelope of the 95% confidence limits for the data points considered as individual points. The latter is an empirical estimate of the amount of variation that can be expected in design values measured in the future. When the trend line is projected into the future, it shows that the design value will decrease below the 1-hour standard by 2007. When viewing this projection line, one must be aware of the estimate of variation that can be expected in the future as mentioned above. This applies to measured values that fall below the trend line as well as values that fall above the line.

Figure 54

1-hour Areal exposure > 120 ppb

The monitoring metric that corresponds to the modeling 1-hour areal exposure is determined by counting the number of monitors that recorded a 1-hour average ozone concentration greater than 120 ppb. For each year this metric was determined for each day when an exceedance of the standard was measured. Figure 55 shows the areal exposure for the five highest days for each year between 1987 and 1996. The areal exposure for the highest day for each year is shown in Figure 56 along with the trend line, which shows decreasing values. The trend line for the highest day is extrapolated to the future in Figure 56. Attainment of the standard would be predicted when the value for the highest day is less than 1.0, but this trend line does not predict a value less than 1.0 by 2007. This analysis could be applied to the second highest day for each year, the third highest day for each year, etc. The values for the fifth highest day for each year is shown in Figure 57 along with the trend line, which also shows decreasing values. This provides information and projections that are not consistent with those of the highest day, so the areal exposure may not be a good metric to use to extrapolate to the future.

Figure 55

Figure 56

Figure 57

1-hour Total exposure > 120 ppb

The monitoring metric that corresponds to the modeling 1-hour total exposure is the monitoring total exposure. It is determined as follows:

> The total exposure for each monitor-day [TE(monitor-day)] is calculated for each day (I) at each monitor (j) as the sum of 1-hour average ozone concentrations in excess of 120 ppb for each hour (k).
>
> The total exposure for each day [TE(day)] is calculated for each day (I) by summing TE(monitor-day) for all the monitors. In this case 13 monitors were used.
>
> The total exposure TE for each year is calculated by summing all daily values for TE(day) for the year.

The highest values for total exposure for a monitor on a day [TE(monitor-day)] from 1987 to 1996 are included in Figure 58. A trend line along with a projection to the future are included in this figure. Attainment of the standard would be predicted when the trend line falls below zero; in this case by 2001. Figure 59 shows the annual total exposure from 1987 to 1996. A trend line along with a projection to the future are included in Figure 59. It is assumed that when this trend line crosses zero, there will be no ozone measurements above the standard. This is predicted to occur in 2005. This trend is more robust than the one illustrated in Figure 58 since in includes data for whole years instead of single days.

The projected trend lines from the measured total exposure indicate that the 1-hour standard will be attained by 2005.

Figure 58

Figure 59

(8) Conclusions

Experts on the FACA Science and Technical Support Work Group have indicated that a minimum of six years of data is necessary to establish trends based on monitoring data. A minimum of six years of data collected in the Houston/Galveston area has been analyzed for ozone and the ozone precursors of NO_x and VOC. This analysis indicates that NO_x and VOC levels have decreased over the Houston/Galveston area. This finding is consistent with estimates of the emissions reductions based on EI information. Since this SIP contains large reductions of precursors that greatly exceed past reductions, it is reasonable to assume that the historical trends established for ozone concentrations will continue in a similar fashion.

Three metrics have been applied to the ozone monitoring data collected since 1987. These metrics are similar to the metrics used for the modeling described earlier. For each of these metrics historical trend lines have been projected to the future. For the design value and total exposure metrics, the projected metric indicates that the 1-hour ozone standard can be expected to be attained by 2007. The data from the areal exposure is not consistent from day to day, so projections to the future may not be useful. Projections of this metric to the future do not predict attainment of the standard by 2007.

These analyses of historical monitoring data, coupled with the modeling, indicate that if the large reductions of ozone precursors defined in this SIP are achieved, the Houston/Galveston area will attain the 1-hour ozone standard by 2007.

r) Access to Modeling Documentation and Data

The modeling appendices referenced in this document can be obtained from Elizabeth Carmack by phone at (512) 239-1652, or by e-mail at ecarmack@tnrcc.state.tx.us. Electronic modeling data files can be obtained from Bright Dornblaser by phone at (512) 239-1978, or by e-mail at bdornbla@tnrcc.state.tx.us.

4) Rate of Progress Target Calculation

Tables 28 and 29 calculate the ROP reductions needed between 2000 and 2007 for VOC and NO_x reductions. These ROP calculations were based on the 1990 Base Year EI, and were calculated using EPA guidance documents. UAM modeling shows that approximately 15% of VOC reductions over the period 2000 to 2007 will be necessary to offset a predicted disbenefit to initial NO_x reductions. The State of Texas believes that VOC reductions will continue to occur as a result of ongoing motor vehicle control programs and new on-road and non-road mobile source programs, and that additional VOC reductions will occur in the point source sector as a result of the full implementation of maximum achievable control technology (MACT) standards. However, the state expects most remaining reductions to come from NO_x controls on non-road, on-road, and point sources. Therefore, out of the 24% ROP reductions required over that period, for the purposes of this initial SIP revision, the state has assigned 9% to VOC control measures, and 15% to NO_x control measures. To satisfy ROP reductions by 2007, the state commits to reduce VOCs by 9% net of growth, and NO_x emissions by 15% net-of-growth. A list of potential control measures that the state is considering can be found in the next section.

Table 28--VOC Target Calculation

Table 29--NOx Target Calculation

5) Attainment Demonstration Target Calculation

Previously in this document, emission reductions required for attainment in the Houston/Galveston nonattainment area have been expressed as a percent of the 2007 projected emissions inventory. In this section, the required emissions reductions are converted to attainment targets, in tons/day, then expressed as percentages of the 1990 base year inventory. The attainment targets are the levels of anthropogenic emissions (VOC and NO_x) which must be reached by 2007 to bring the area into attainment of the 1-hour standard. In other words, what are the maximum levels of VOC and NO_x emissions which can occur in 2007, according to the modeling, yet the area be in attainment of the 1-hour standard? These attainment targets may be thought of as 2007 emissions *budgets* for the two pollutants. Because the FCAA Amendments established 1990 as the base year against which emissions are measured, it is convenient to convert the reduction percentages formerly expressed in terms of the 2007 projected inventory in 1990 terms. In this way, reductions designed to meet the attainment target become directly comparable (percent-by-percent) with ROP reductions.

It is important to note that the attainment targets discussed here were established using across-the-board emissions reductions, and that actual controls will be applied to specific sources. Thus, once specific controls have been developed to reach the attainment target, the model must be used to determine whether any particular set of controls will result in attainment, even though the attainment target is met. Conversely, modeling may be used to show that some well-designed control strategies can lead to attainment with less stringent attainment targets than those derived herein. The commission will continue to use modeling to assess specific control measures and combinations thereof to find the most cost-effective solution to ozone pollution in the Houston/Galveston nonattainment area.

Attainment Target for NO_x

As described earlier in the Weight-of-Evidence section of this SIP, the modeling indicated that the September 10, 1993 episode was the "controlling day" of the episode--in other words, more reductions would be needed on September 10 to attain the standard than on the other days. On this day, in the best case, a reduction of approximately 65% of anthropogenic NO_x (based upon the projected 2007 emissions inventory) would be required to attain the standard, while in the worst case a reduction of approximately 85% would be required. The controlling day's cutpoints (65% and 85%) set the range of reductions needed to attain the standard by 2007 for this episode. However, the actual reduction required varies from day to day across the four modeled episode days. To determine day-specific reduction percentages in the worst-case (the 2007 base inventory), a visual analysis of Figure 37 was performed to determine the closest integer percent to the point where the ozone concentration intersects the 124 ppb line. Reduction percentages for the best case (Alternative Inventory I with OTAG 5c regional reductions) were determined by first performing a visual analysis of Figure 42 (Alt. Inventory I), then subtracting 5% (assumed benefit of OTAG 5c reductions).

Like the reduction percentages, modeled emissions projected to 2007 vary from day to day as well. Table 30 shows the modeled 2007 NO_x emissions for each day, for both the best and worst cases (the base 2007 inventory and Alternative Inventory I), as well as day-specific best- and worst-case reduction percentages.

Also shown in Table 30 is the 1990 baseline inventory NO_x emissions level of 1330 tons/day.

The Attainment target is the lowest target value from among the four days, which occurs on September 10 for both the best case and worst case. Thus the attainment target for NO_x is 230 tons/day for the worst case, which represents a reduction of 83% from the 1990 baseline. Total required reductions in this case are 1100 tons/day, as shown in Table 30. In the best case, the attainment target is 342 tons/day, which is a reduction of 62% from the (Alternative I) baseline 1990 emissions. The best-case required reductions are seen to be 566 tons/day (again, this lower reduction target is predicated upon the assumption that the Alternative I baseline EI for 1990 is a better representation of reality than is the 1990 baseline inventory).

These percentages are then converted to tons per day reductions by subtracting the target amount from the 1990 basline NO_x emissions. The creditable reductions to 1999 (100 tons per day of mobile source and point source reductions) are then subtracted. This yields a target of required remaining reductions. For September 10, the best case target is 466 tons per day, and the worst case is 1000 tons per day.

Table 30: Attainment Target Calculations for 2007 NO_x Emissions in the Houston/Galveston Area

	Episode Day			
	9/8	9/9	9/10	9/11
Required reduction from 2007 base EI				
Worst-case	83%	78%	85%	80%
Best-case	62%	53%	67%	61%
2007 Projected NO_x emissions (tons/day)				
Worst-Case (Base 2007 EI)	1467	1457	1531	1376
Best-Case (Alt. EI I)	986	978	1035	930
2007 Attainment target (tons/day)				
Worst-case	249	321	230	275
Best-case	375	460	342	363
1990 baseline NO_x emissions (tons/day)	1330			
Adjusted for Alt. EI I Assumptions	908			
Required reduction relative to 1990 baseline				
Worst-case	82%	77%	83%	80%
Best-case	59%	49%	62%	60%
Required Reduction in tons/day				
Worst-case	1081	1009	1100	1055
Best-case	533	448	566	545
Reductions by 1999 from 9% SIP	(100)	(100)	(100)	(100)
Remaining required reductions				
Worst-case	981	909	1000	955
Best-case	433	348	466	445

Attainment Target for VOC

In addition to the NO_x reductions discussed above, modeling indicated that a 15% reduction in VOC from the 2007 base would mitigate any significant NO_x disbenefits. Thus, a reduction of 15% from the 2007 base VOC EI is used to determine the attainment target for VOC and the associated reduction from the 1990 base. Table 31 shows the modeled 2007 anthropogenic VOC emissions for each day.

Table 31: Attainment Target Calculations for 2007 VOC Emissions in the Houston/Galveston Area

	Episode Day			
	9/8	9/9	9/10	9/11
Required reduction from 2007 base EI	15%			
2007 Projected VOC emissions (tons/day)	831	838	849	847
2007 Attainment target (tons/day)	706	712	722	720
1990 baseline VOC emissions (tons/day)	1064			
Required reduction relative to 1990 baseline	34%	33%	32%	32%
Required reductions in tons/day	358	352	342	344
Reductions by 1999 from 15% & 9% SIPs	(333)	(333)	(333)	(333)
Remaining required reductions in tons/day	25	19	9	11

Table 31 shows that a reduction of 25 additional tons per day of VOC emissions would be sufficient to achieve the 15% target on any of the four episode days.

6) Creditable Reductions Occurring by 2007

The EPA issued Interim Implementation Guidance on December 29, 1997. This guidance stated that states must submit, as part of their April 1998 Attainment Demonstration submittal, a list of measures and regulations and/or a strategy including technology forcing controls needed to meet ROP requirements and attain the 1-hour standard. The State of Texas has listed a set of control measures and strategies that it believes could be used to achieve the 1-hour ozone standard in the Houston/Galveston area. Due to the extremely short time frame between the IIG's issuance and the due date of this submittal, the state has not attempted to select from among this list, and it makes no commitment that if an item appears on this list it will be selected for implementation in the Houston/Galveston area. This list is intended to function as the beginning to an open public dialogue on future efforts to achieve the 1-hour ozone standard in the area. The state intends to use the time from the date of this submittal until the end of 2000, (which is when the IIG guidance stipulates that a complete control strategy including adopted control measures must be submitted to EPA) to select the optimum control strategy for Houston/Galveston.

Table 32 is a list of potential NO_x control strategies, and Table 33 lists potential VOC control strategies. Each list is divided into three sections, as described below. Information about how the reductions were calculated can be found in Appendix H.

Please note that all projections were made using a high-level analysis of potential emission reductions available from a control strategy and applying it to the Houston/Galveston emissions inventory. This estimation is performed for the purpose of giving the reader an idea of the order of magnitude of reductions available from a control strategy only, not to commit to a particular emissions number or budget. Actual emission reductions can only be determined by development of a rule proposal, and a detailed analysis of the exact emission points that the rule will apply to. This caveat applies to all source categories. These numbers are subject to further refinement at the discretion of the state.

Anticipated Federal Control Strategies

This section is an attempt to quantify national rules that will be implemented before 2007. Staff used available national rule proposals or pre-proposals, EPA staff guidance, information from the OTAG final report, and other sources to prepare this list. The commission does not believe that this is a complete list. There are certain federal control programs, such as future MACT standards and the Tier 2 Federal Motor Vehicle Control Program standards, which EPA is required to promulgate before 2007. This table excludes those programs in many cases because no information exists to indicate what the level of creditable reductions might be. In all cases, this information is preliminary and subject to further refinement and change as the national rules are promulgated and the state has an opportunity to apply them to the emissions inventory.

State Proposed Regional Strategy

Under the leadership of Governor Bush, the state is preparing a new, comprehensive, regional strategy for the eastern portion of the state. This strategy will have an important effect on Houston in two ways. There will be certain elements that apply to the Houston/Galveston nonattainment area, such as the national Low Emission Vehicle Program. Beyond that, however, due to the broad regional nature of the proposed controls, there will be less ozone and ozone-forming precursors entering the Houston/Galveston airshed. Further details of this plan are being worked out in a separate effort.

Another line item on the chart shows “Excess reductions from the 9% SIP.” Due to splitting up creditable reductions between VOC and NO_x control strategies to meet the 9% target, there was an excess of both VOC and NO_x reductions, which is being carried forward into this SIP. These credits are being included as early reductions to meeting the attainment target.

The state is also working on a methodology to take emission reduction credits for the Clean Air Responsibility Enterprise (CARE) program and other voluntary industry reduction efforts. Quantified tons per day emission reduction were not available at the time of proposal, but will be investigated for future submittals. The state invites public comment that would assist them in quantifying these reductions.

As a future part of the state's regional strategy, the state also plans to study the potential benefits of the implementation of California Clean Diesel and of various SO_2 controls.

Potential "Local Options" Control Strategies

This category represents those programs in which the local area will assist in selecting the optimum preferred package of control strategies for the Houston/Galveston area. The state believes that decisions about the inclusion of certain programs, such as the expansion of the current vehicle I/M program, are most properly local decisions. The state will evaluate for inclusion in the SIP those programs for which there is local support.

Therefore, the state has not attempted to quantify other control programs during the proposal stage. This will allow equal public participation from all stakeholders during the comment phase of this proposal. The state invites the public to suggest additional control strategies in their testimony. The state will attempt to quantify these strategies for the adoption phase of this SIP, although by doing so, it does not commit to adopt any specific control measure. Additional control measures may be suggested by stakeholders and developed during the strategy selection process.

The state believes that the wording of the IIG that allows the state to submit a strategy to meet ROP requirements and attain the 1-hour standard also allows the state to develop this SIP strategy. The state believes that the nature of the control strategies for the SIP will be so broad and sweeping that they will require significant public input. The state believes that groups such as the Houston-Galveston Area Council (HGAC) and other stakeholder groups will assist in developing the best plan possible.

Houston Air Excellence in Leadership (HAXL) Project

The City of Houston has funded a project to explore a health-based, cost/benefit approach to examining and improving air quality in the Houston area. The state believes that if the city can work with EPA and other stakeholders to develop a consensus plan that will achieve optimal public health benefits for the Houston/Galveston area, that it could form an important component in future SIP development for the area.

The State of Texas believes that progress toward attainment in Houston is an ongoing, evolving process, and that any research which leads to additional information about Houston's air quality, health impacts to citizens, and wise selection of control strategies, will contribute to that process. There will be additional SIP revisions to the attainment demonstration over the next several years, and the state envisions that this project could contribute to the development of future SIPs. The state solicits public comment on the appropriate role for the HAXL project to play in future SIP development.

Table 32 Potential NO_x Control Strategies

Federal Control Strategies

Control Measure	Estimated 2007 Emissions Reduction (tpd)
On-Road Heavy Duty Diesel Standards *(proposed in 1997--effective date 2004)*	6.98
Heavy Duty Diesel Non-Road *(began phase-in 1995--phase-in complete by 2008)*	123.59
Locomotives *(final rule--begin phase in 1999--complete by 2005)*	8.52
Reformulated Gasoline, FMVCP Tier I, I/M *(RFG effective in 2000--other programs in place currently)*	39.93

State Control Strategies

National Low Emissions Vehicle Program--Core Counties *(currently under negotiation--could begin phase-in MY2001)*	12.15
National LEV Program--perimeter counties--200km	7.44
Reformulated Gasoline--perimeter counties--200km	12.38
NO_x RACT applied to perimeter counties--200km	80.00
Excess Reductions from 9% SIP--Carryover	23.41
Voluntary Industry Reductions	Amount not available at time of proposal
Point Source Combustion Modification--Tier I--Core Counties	241.00
Point Source Flue Gas Controls--Tier II--Core Counties	584.00
Point Source Tier I +Tier II=Tier III--Core Counties	620.00
Point Source Tier I--Perimeter Counties	333.00
Point Source Tier II--Perimeter Counties	811.00
Point Source Tier III--Perimeter Counties	864.00
Reformulated Gasoline for Non-Road Sources	Amount not available at time of proposal

Local Options Control Strategies

Additions will be made based on public comment	

Table 33 Potential VOC Control Strategies

Federal Control Strategies

Control Measure	Estimated 2007 Emissions Reduction (tpd)
Small Gasoline Engines *(began phase-in 1995--phase in complete by 2005)*	63.72
Heavy Duty Diesel Non-Road *(began phase-in 1995--phase-in complete by 2008)*	18.41
Locomotives *(final rule--begin phase-in 1999--complete by 2005)*	.13
Reformulated Gasoline, FMVCP Tier I, I/M *(RFG Phase II begins in 2000--other programs in place)*	29.06
Recreational Marine Engines *(began phase -in 1995--complete by 1998)*	23.57
Commercial Aircraft *(rule took effect in 1994)*	1.17
RFG Non-Road Mobile Sources *(RFG Phase II begins in 2000)*	4.6
MACT Standards--Core Counties *(*Please see note below)*	Amount not available at time of proposal
MACT Standards--Perimeter Counties out to 100km	Amount not available at time of proposal
Reformulated Gasoline Phase II for Storage Tanks out to 100km	Amount not available at time of proposal
Reformulated Gasoline Phase II for Loading Racks out to 100km	Amount not available at time of proposal

State Control Strategies

National Low Emissions Vehicle Program--Core Counties *(currently under negotiation--could begin phase-in MY2001)*	4.66
National LEV Program--perimeter counties--100km	0.95
Reformulated Gasoline out to 100km	16.33
VOC RACT out to 100km	7.90
Stage I out to 100km	23.91
Excess VOC Reduction Carryover from 9% SIP	10.29
Voluntary Industry Reductions	Amount not available at time of proposal

Local Options Control Strategies

Additions will be made based on public comment	

*Historically, most MACT standards have been promulgated 1-2 years after their required promulgation date. There are approximately 30 MACT standards that were slated to be promulgated by 1997. Most appear to be running 1-2 years late for their predicted promulgation date. There are approximately 60 standards in the 2000 bin. Current EPA information is that most are on track for promulgation by 2000. Compliance dates for MACT standards are typically three years after promulgation. Therefore, even if the historical pattern of delay occurs for the 1997 bin standards, it's reasonable to assume that sources will be in compliance by 2002, and that the 2000 bin standards will be promulgated and generating emission reductions by 2005.

Options for Emission Reduction Standards
The implementation of more stringent NO_x and/or VOC limitations needed to achieve the ozone standard will involve higher control costs for regulated industries. In order to achieve required reduction levels while promoting flexibility and reasonable control costs, it may be necessary for the state to examine its regulatory approach to specifying emission reduction standards. Historically, the state has relied on various market-based incentive programs to provide more flexibility to regulated sources.

The state's current ozone control regulations, under Chapter 115 for VOC and Chapter 117 for NO_x, limit emission rates rather than total emissions. A source's total emissions are a function of the emission rate (emissions per unit of input or output activity) and the activity level (a measure of the source's production, fuel or raw material use, or other factor correlated to emissions). From the regulated source's standpoint, an advantage of not having total emissions limited by regulatory requirements is that the source activity level is relatively free from constraints. A disadvantage is that the source does not have the freedom to manage its emission reduction activities by balancing both a unit's emission rate and its activity level. For example, as long as a regulated unit stays within the prescribed emission rate, generally there are no limitations on its activity level. However, it is not an acceptable compliance option for the unit to reduce its operating hours or production rate while increasing its emission rate above the prescribed level, even if total emissions do not increase as a result. This lack of flexibility may cause rate-based standards to be more costly than emission-based standards reflecting comparable reduction levels.

Setting emission-based standards by means of an emissions budget ties more directly to the goal of attaining the ambient air quality standard, since ultimately it is the sum total of emissions that causes the standard to be exceeded, not the emissions per unit of activity. This would require shifting the regulatory focus from unit-based emission standards to an overall emissions budget or cap which could not be exceeded. The urban airshed modeling completed in the Fall of 1997 predicts emission levels that would result in attainment. These levels could be used to develop emissions budgets for Houston/Galveston sources.

In the emissions budget (also known as "cap and allocation") system, allocations are created by distributing a fixed tonnage budget among affected sources. These allocations are based on a performance standard, actual emissions, or some combination. Each source receives in advance an assigned number of allowances, in tons, for a specified period of years. At the end of each season or year, the total amount of emissions allowances is reconciled with the emissions budget.

The state will continue to investigate and develop appropriate market-based incentive programs to facilitate ongoing control strategies necessary to attain the ozone standard. The documentation and operating experience for NO_x trading programs is more extensive, but the same basic principles apply to VOC trading.

7) Commitment Schedule for Future SIP Submittals

The State of Texas commits to submit the remaining components of the attainment demonstration for the Houston/Galveston nonattainment area.

- The state plans to submit the SIP to EPA by December 15, 2000.
- Public hearings are planned for the first week in October 2000.
- The commission plans to propose the SIP on or before September 1, 2000.

- ♦ Control strategy/SIP development will occur between March 1, 1999 and August 31, 2000.
- ♦ Control strategy selection and preliminary development will occur between May 1, 1998 and February 28, 1999.

10. SIP REVISIONS FOR THE REDESIGNATION AND MAINTENANCE PLANS (No change.)

11. SIP REVISIONS FOR POST-96 RATE-OF-PROGRESS (Revised.)

a.-b. (No change.)

c. Houston/Galveston Ozone Control Strategy (Revised.)

1) General (No change.)

2) Estimated Emission Reductions

a) 9% Targeted Reductions

Using the best technical guidance and engineering judgement available at the time, the State of Texas calculated emissions reductions available from the enhanced monitoring rule that was to be part of the Title V permitting program. The enhanced monitoring rule was later revised and transformed into the Compliance Assurance Monitoring (CAM) Rule. At the time, Texas maintained that their calculation methodologies still accurately reflected the amount of creditable reductions available. EPA has indicated that they disagree with the calculation methodologies used by the state and intend to disapprove the 9% SIP as a result.

EPA has also indicated that the emission reduction credits claimed for the Texas Clean Fuels Fleet program are not approvable due to a legislative change to that program. The state plans to submit a SIP revision for this program in a separate action, but has removed the credits claimed in the 9% SIP in this action.

Therefore, the State of Texas proposes a revision to the 9% SIP. This SIP revision changes the reductions claimed by the state toward the 9% emissions target.

Table 1 shows the amount of reductions needed to meet the VOC target of 6% ROP reductions. Table 2 shows the amount of reductions needed to meet the NOx target of 3% ROP reductions. The two combined will achieve the 9% ROP reductions needed to demonstrate compliance with ROP requirements for 1999.

Table 1--VOC reductions

Table 2-NOx reductions

b) Stationary and Area Source Controls

As previously stated, EPA has indicated that they disagree with the calculation methodologies used by the state for the CAM rule and intend to disapprove the 9% SIP as a result.

In 1993, the staff estimated the NO_x reductions from the state's Chapter 117 NO_x RACT rules, as 10% of the Houston/Galveston point source inventory, based on their best engineering judgement. Problems, such as the lack of differentiation and overestimation in the EPA NO_x emission factors for external combustion sources, resulted in a high degree of uncertainty in the NO_x baseline rates for boilers and heaters. This, in turn, made it difficult to estimate the reductions that the selected emission standards would achieve. The flexible structure of the RACT rule (compliance alternatives include emission averaging, source cap, and trading) also made it difficult to estimate emission reductions without more specific information developed by the operators of the plants subject to the rule.

The RACT rule required companies to submit initial control plans (ICPs) in 1994. The ICPs were designed to provide a more accurate assessment of the NO_x reductions necessary to comply with the rule's emission limits, without forcing companies to lock into specific measures before the rule compliance date. These plans were submitted and given an initial review by agency staff in 1994 and 1995. Emission units anticipated to be controlled were identified in the ICPs. The Engineering Services Team assembled a database of the information contained in the ICPs. From this database, the number of units and the units anticipated to be controlled by the rule are summarized in Table 3. The figures are rounded because the staff review of the ICPs and completed database was preliminary. The staff is now re-examining the information. Chapter 117 did not require the ICPs to contain estimation of the emission reductions. The staff is currently linking the database account, facility identification, and emission point numbers of the 330 pieces of equipment anticipated to be controlled to the corresponding 1990 emissions inventory emission rates in order to provide a more definite estimate of the reductions from the rule.

The final control plan (FCP), due at the rule compliance date, includes the requirement that companies relying on the flexible compliance alternatives provide enforceable emission limit information. The FCPs will provide the most accurate information on the scope of the rule's reductions. Since there will have been an unusually long period, more than five years, between the submittal of the ICP and the FCP, there will be numerous changes in units selected for control, and in the resulting emission reductions.

Table 3: Anticipated number of units to be controlled by NO_x RACT rule in H/GA

Unit Type	Total number of units listed in ICPs	Number of units not requiring control	Number of units requiring control
Boilers/Process Heaters	1500	1350	150
IC Engines	850	710	140
Gas Turbines	180	130	50

Additionally, adjustments to the 9% ROP SIP are proposed to reduce the projected VOC reduction credits from the two pulp and paper mills in the area. The scope of the pulp and paper rule changed between the December 17, 1993 proposal and the signing of the final rule on November 14, 1997. The final rule covers fewer source categories at pulp and paper mills, so the originally anticipated estimate of 60% rule coverage of the total plant VOC emissions (with 90% control efficiency, resulting in 54% overall VOC reduction), used in the original 9% ROP SIP, is no longer realistic. The EPA now estimates the overall VOC reductions at 49% according to their fact sheet on this rule. Also, rather than having a compliance date by 2000, the compliance date is eight years after publication of the final rule. If the signed rule is published in the *Federal Register* in 1998, the compliance date will be in 2006, so the reductions will not be creditable for the 1997-1999 ROP period.

In January 1998, the two mills in the Houston/Galveston area provided preliminary information on the projected reductions from both the MACT rule and the Chapter 115 vent gas standard for pulp and paper sources. The Chapter 115 rule, which has a November 15, 1999 compliance date, lowers the exemption for pulp and paper sources from stream concentrations of 30,000 ppmv to 612 ppmv. The mills have reviewed their emission sources and preliminarily determined that the reductions from Chapter 115 would only achieve a reduction of 0.15 tons per day. However, their analysis also indicates that they have already achieved creditable reductions of between 2-3 tpd since 1990, due to various plant upgrades covered by New Source Review permits. The state invites comment on these creditable reductions during the public comment phase for this SIP.

This SIP revision revises the reductions claimed by the state toward the 9% emissions target. Table 4 shows the VOC reductions that will achieve a 6% net of growth reduction from a 1990 baseline by 1999. Table 5 shows the NO_x reductions that will achieve a 3% net of growth reduction from a 1990 baseline by 1999. Both tables also contain contingency measures. Out of the 3% required contingency measures, 0.75% (or one quarter of the total) is being met by VOC controls. The remaining 2.25%, (or three-quarters), is being met by NO_x control strategies--specifically the NO_x RACT program mentioned above.

Table 4 with VOC reductions

Table 5 with NOx reductions

12. SOCIAL AND ECONOMIC CONSIDERATIONS OF THE PLAN (Revised.)

a.-h. (No change.)

i. Evaluation of the Houston/Galveston Attainment Demonstration (Revised.)

13. FISCAL AND MANPOWER RESOURCES (No change.)

14. HEARING REQUIREMENTS

a.-h. (No change.)

i. Public Hearings for the Houston/Galveston Attainment Demonstration (Revised.)

The state plans to conduct public hearings for this SIP on March 12, 1998 at 7:00 p.m. and on March 13, 1998 at 10:00 a.m. at the Houston/Galveston Area Council's offices at 3555 Timmons Lane, Houston. Staff will conduct a question and answer period one-half hour prior to the start of each hearings. The close of the public comment period will be on March 20, 1998.